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Journal
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Devoted to Science and the Mechanic Arts

Vol. 237 FEBRUARY, 1944 No. 2

HISTORICAL NOTES ON THE DETERMINATION OF DISTANCE BY TIMED RADIO WAVES.

BY

C. D. TUSKA.

(*Continued from January issue.*)

PATENT APPLICATIONS FILED IN 1930.

U. S. Patent 2,045,071, which issued on a patent application filed in 1930 by Espenschied,[42] discloses an altimeter for aircraft. The altimeter corresponds generally to Bentley's but differs therefrom in employing in one species a combined detector oscillator which is shown here as Fig. 8. Other species are disclosed in the patent.

Hart,[43] Wolf,[44] and Turner [45] of the Submarine Signal Company filed one or more applications, on which patents issued as follows: Hart's patent 1,924,156 corresponds to the pulse systems of Breit and Tuve and to Goubau's device. Figure 1 of the Hart Patent is shown here as Fig. 9. The transmitter consists of a high frequency oscillator 3, a biased amplifier 5, and a modulator 6. Quadrature phase currents are derived from the modulator and are applied to the deflecting plates of the cathode ray indicator 12 to produce a rotating field which establishes a circular trace. The receiver 22 has its output circuit connected to the cathode 15 and anode 16 of the cathode ray tube to produce signal indicating deflections.

Wolf's Patent 1,924,174 will be described by reference here to Fig. 10 which is Fig. 1 of the patent. A high frequency oscillator 9 is connected to a biased amplifier 3. The amplifier input is also connected to a low frequency modulator 1. The amplifier output is applied to a loop antenna 8. The receiver consists of a loop 17, an amplifier 18, a biased amplifier 20, a detector 26, and a neon tube 21. The biased amplifier 20 of the receiver is coupled to the biased amplifier 3 of the transmitter

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through a variable retardation network 24. The variable elements of the retardation line may be driven by a motor. A suitable scale attached to the motor is illuminated stroboscopically by the neon tube 21. When the echo signals and the signals from the retardation line coincide, the biased amplifier 20 of the receiver passes the signals to the detector 26 and hence to the neon tube 21. Modifications are described in the patent.

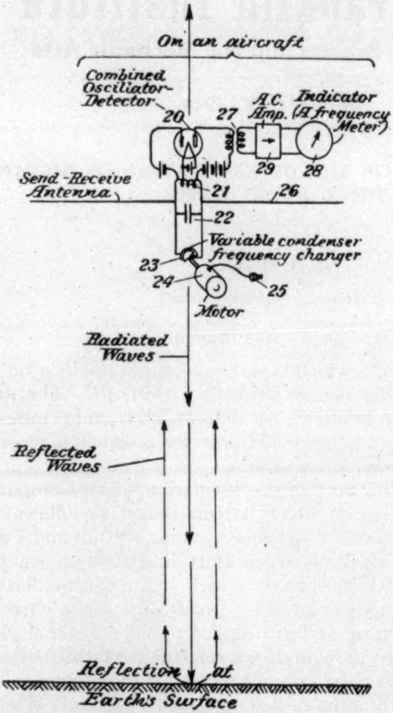
On an aircraft
Combined Oscillator-Detector
20
27
A.C. Amp.
Indicator (A frequency Meter)
29
28
Send-Receive Antenna
21
26
22
Variable condenser frequency changer
23
24
25
Motor
Radiated Waves
Reflected Waves
Reflection at
Earth's Surface

FIG. 8

V.2
194

Turner Patent 1,982,271 discloses several species of distance measuring means. Figure 4 of the patent is representative and is here reproduced as Fig. 11. The transmitter consists of a crystal controlled oscillator 9, whose output currents are applied to a loop antenna 35. The currents applied to the loop are also applied to a phase splitter 10, 34 and hence to the deflecting electrodes 30–31, and 32–33 of a

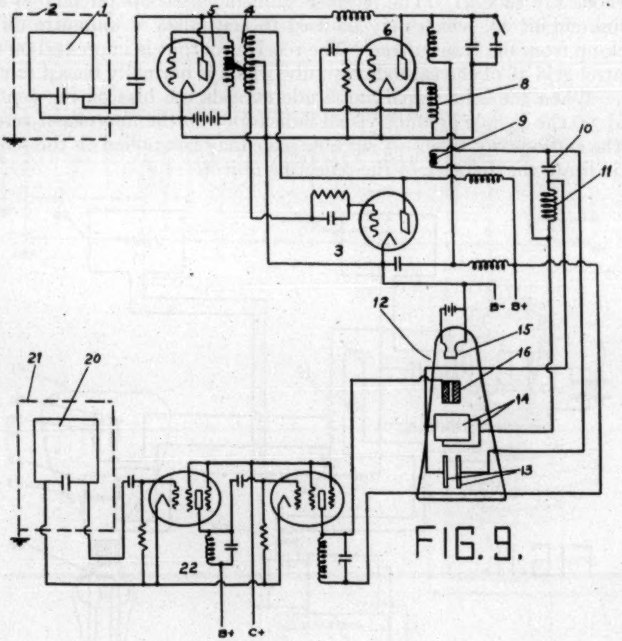
B-
B+
B+
C+

FIG. 9.

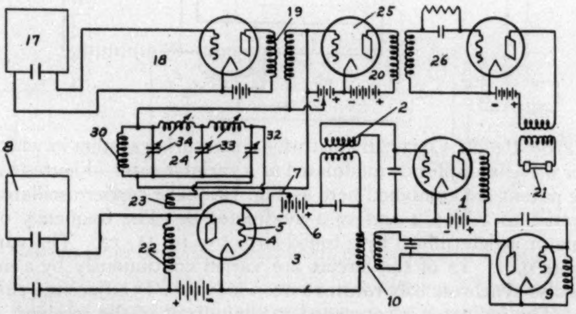

FIG. 10.

cathode ray tube 21. The receiver 37 includes a loop antenna 36 and a link circuit 22, which may be used to neutralize or minimize direct pick-up from the transmitter. The receiver output is impressed on the control grid 38 of the cathode ray tube which is normally biased to cut-off. When the echo signal amplitude exceeds the bias on the control grid 38, the signals produce visual indications on the fluorescent screen of the cathode ray tube. A suitable scale may be applied on the screen to indicate the distance of the reflecting object.

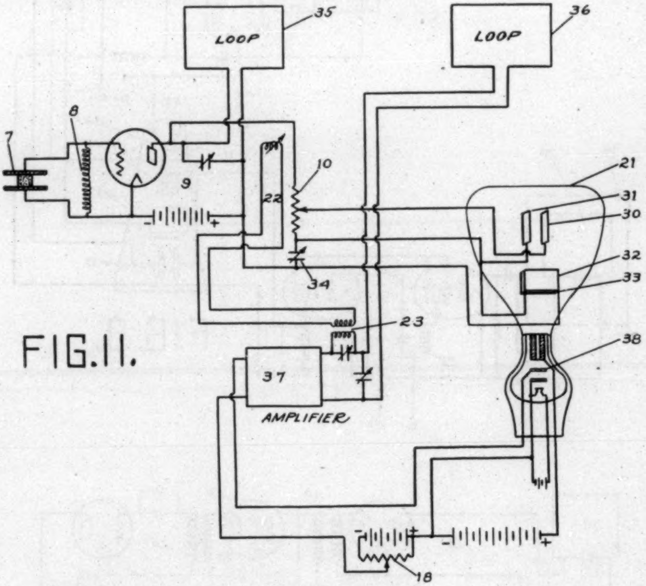

FIG. 11.

Hart[46] Patent 1,993,326 illustrates a measuring system in which the carrier wave is amplitude modulated at a variable rate. Figures 2 and 3 of the patent are combined here as Fig. 12. The carrier oscillator 7 is connected to a loop 4 and to a modulator 8. The frequency of the modulator is determined by a tuned circuit 9, 10, 11, 12. The variable elements 9, 11, 12 of the circuit are varied continuously by a motor, which also synchronously rotates a neon indicator 15 adjacent a suitable scale. The indicator is connected to the output of the receiver. The receiver includes a loop antenna 17, an amplifier 18, and a detector 19. The detector is biased to respond only when the radiated signal and the reflected signal are received simultaneously. The oscillator 32 is used to form beats for an aural signal which is applied to telephone receivers 33.

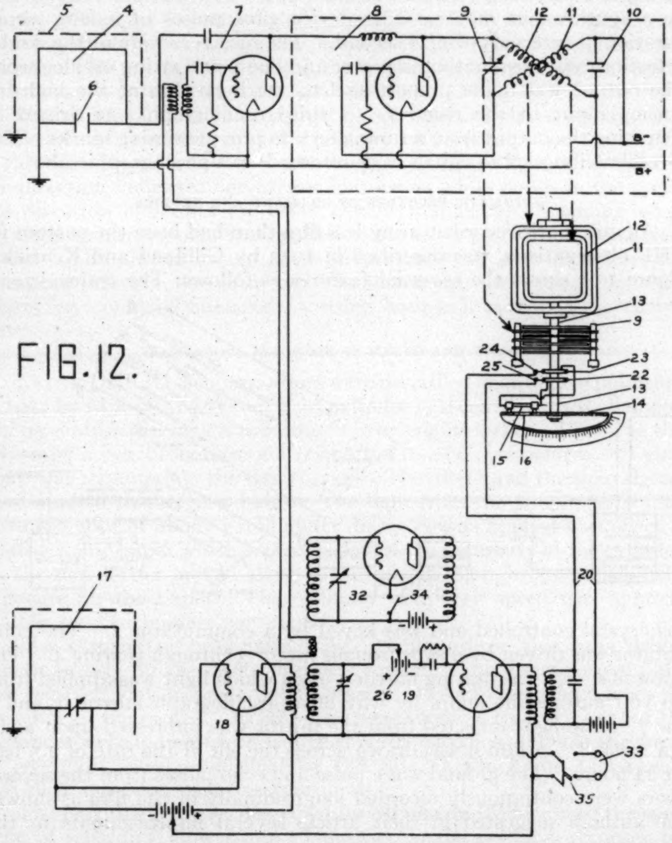
FIG. 12.
5
4
7
8
9
12
11
10
6
B-
B+
12
11
13
9
24
23
25
22
13
14
15
16
17
32
34
20
18
26
19
33
35

SIMULTANEOUS DISTANCE MEASUREMENTS OF SCHAFER AND GOODALL.

In 1931 Schafer and Goodall [47] made "simultaneous" measurements of the KHL by transmission and reception on two frequencies after the manner proposed by Hafstad and Tuve.[38] The transmitter for the lower frequency (1604 kc.) consisted of two 250 watt tubes connected in pushpull and coupled to a simple "L" antenna. The transmitter for the higher frequency (3088 kc.) was of the oscillator-amplifier type employing two 5 kw. tubes in the final stage. The pulses were established by a grid bias voltage, which was interrupted by a contact wheel driven by a synchronous motor. This device gave pulses of 0.0005 second duration at intervals of 1/30 second. The receivers were of the double detection type terminating in power amplifiers and string oscillographs. The output was made proportional to the logarithm of the high-frequency input to the receiver. A third oscillograph was driven by distorting the output from a tuning fork to provide timing marks. The several oscillographic signals were recorded on a photographic film.

AUTOMATIC RECORDER OF GILLILAND AND KENRICK.

An automatic recorder, using less film than had been the custom for KHL observations, was described in 1932 by Gilliland and Kenrick.[48] Figure 13 * shows the essential features as follows: The transmitter 1 was crystal controlled and was keyed by a commutator 2. The commutator was driven by a synchronous motor 3 through gearing 4. The motor also drove a rotating mirror 5 upon which light was applied from a 6 volt automobile lamp, by way of an oscillograph mirror 6, and a lens 7. The light reflected from the mirror was impressed upon a slit in a mask 8. A film 9 was drawn across the slit at the rate of 2.5 feet per 24 hours. The ground wave pulse and echo pulses from the several layers were continuously recorded longitudinally of the film as shown. The authors suggested in their article several improvements in the apparatus.

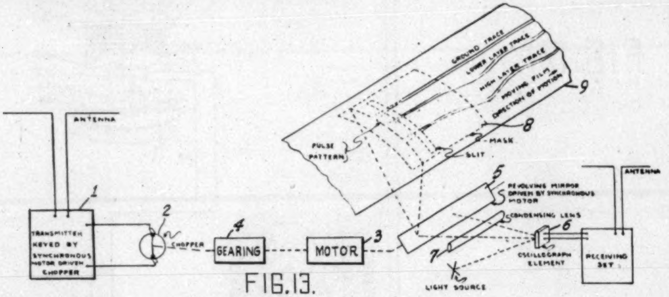
ANTENNA
1
TRANSMITTER KEYED BY SYNCHRONOUS MOTOR DRIVEN CHOPPER
2
CHOPPER
4
GEARING
MOTOR
3
GROUND TRACE
LOWER LAYER TRACE
HIGH LAYER TRACE
MOVING FILM
DIRECTION OF MOTION
9
8
MASK
SLIT
PULSE PATTERN
5
REVOLVING MIRROR DRIVEN BY SYNCHRONOUS MOTOR
CONDENSING LENS
6
7
OSCILLOGRAPH ELEMENT
LIGHT SOURCE
ANTENNA
RECEIVING SET

FIG. 13.

DUAL INDICATING CATHODE RAY TUBE OF SCHAFER AND GOODALL.

Schafer and Goodall [49] modified their 1931 apparatus [47] according to their paper published in 1932. The lengthy and tedious process of

---

* Note: Figures 13, 14 and 15 are produced through the courtesy of the Institute of Radio Engineers.

measuring the intervals on photographic film was overcome by observing the signals on a cathode ray tube. The observed signals were reported by telephone and the data recorded. In the modified apparatus a pair of relaxation oscillators, controlled by a 60 cycle current source, were used to control the transmitters. The transmitters were operated at different carrier frequencies at the rate of 30 pulses per second. The pulses from one of the transmitters were 1/60th second later than the pulses from the other.

The pulses of different frequencies were separately received. The receiver outputs were of opposite polarity, and were applied to one pair of the deflecting electrodes of a cathode ray tube so that deflections in one direction indicated one carrier frequency; while pulses in the opposite direction indicated the other carrier frequency. A timing wave from the 60 cycle source was applied to the other pair of deflecting electrodes. The timing sweep gave an accuracy of ± 2 kilometers for distances between 100 and 350 kilometers. A total range of 2,500 kilometers could be observed by using both half cycles of the timing wave.

CONTINUOUS RECORDER OF MIMNO AND WANG.

Two novel KHL echo recorders were described in an article published in 1932 by Mimno and Wang.[50] A cylinder 17.8 centimeters in diameter and 95 centimeters long was mounted in an engine lathe. The lathe was driven by a synchronous motor connected to a 60 cycle source. A glow lamp was mounted on the tool carrier. The direct and the echo signals were applied to the glow lamp. The light from the lamp was focused so that a spot of about $\frac{1}{4}$ millimeter diameter was applied to a sheet of photographic paper which was attached to the periphery of the cylinder. As the tool carrier moved along the unmodulated light spot left a helix exposure on the paper. The ordinary periphery speed was approximately 400 centimeters per second.

The transmitter was pulsed by a commutator that was driven synchronously on the 60 cycle power source. The ground wave pulse was received first and recorded as a series of black dots which form the base line of the record. Echo pulses were likewise recorded so that the distances were indicated on the peripherial coordinate; while the times of reception were established by the rate at which the tool carrier travelled along the base line coordinate.

The portable recorder described by Mimno and Wang used the same type of recording glow lamp. However, in the portable recorder the lamp was stationary. The light from the recorder was projected along the axis of a rotating mirror, and thereafter focused on the photographic paper strip. The strip was moved slowly in the direction parallel to the axis of the mirror. The strip was formed into a section of a cylinder as it passed the rotating spot of light so that the axis of the cylinder coincided with the axis of the rotating mirror. Thus the focus was maintained as the light travelled across the moving photographic strip. The longitudinal motion of the strip and the rotational motion of the mirror were produced by a synchronous motor. The transmitter and the recorder were connected to a common power supply for synchronizing purposes. The recorders were used to record the effects of the total solar eclipse of August 31, 1932, on the KHL.

CONTINUOUS RECORDER OF KENRICK AND PICKARD.

A 1933 paper by Kenrick and Pickard [51] describes the continuous recorder which they used to record KHL echoes during the eclipse of 1932. Several arrangements were used: In one arrangement a glow lamp, including a focusing lens, was rotated by a synchronous motor so that the focused light swept across a slit in a camera. The camera included a drum which was rotated by a telechron chart movement mechanism. A photographic film was arranged to be wound up on the moving drum so that one camera loading was sufficient for several hours of recording. The signals were recorded so that the distances were indicated along the length of the drum while time was indicated along the longitudinal axis of the film. Timing marks were applied by short circuiting the recording lamp by contacts driven by a telechron clock. The transmitter and recorder were operated on the same power supply so that synchronous operation was obtained. The initial phasing of the recorder and transmitter was established by trial. In a modification the recording lamp was made stationary and the light beam from the lamp was rotated by a suitable optical element which was rotated by the synchronous motor.

GILLILAND'S MULTIFREQUENCY AUTOMATIC RECORDER OF IONOSPHERE HEIGHTS.

Since the KHL responds differently to different frequencies, it became desirable to use a plurality of frequencies in exploring the layer. This was accomplished by a multifrequency recorder described by Gilliland [52] in 1933 and published in his paper of 1934. The arrangement of the transmitter is shown in Fig. 14. The chopper circuit included a commutator driven by a synchronous motor. The commutator was included in the grid circuit of a UX 852 tube which keyed a second UX 852. The second UX 852 was connected as an oscillator which energized the input circuits of three UX 860 amplifiers connected in parallel. The output of the amplifiers was applied to several antennas for radiating carriers having frequencies of 2,500 to 4,400 kilocycles.

The amplifiers and oscillators were tuned throughout the carrier frequency range at a uniform rate of 200 kilocycles per minute by means of variable capacitors. The synchronous motor, driving the commutator, also furnished the driving power for the variable capacitors in the transmitter and for tuning the receiver. Cams and gears were used to maintain proper tracking of the several devices and suitable operating ratios. The receiver output was applied to a photographic recorder of the type described by Gilliland and Kenrick [48] in 1932. The arrangement thus briefly described was adapted to sweep through its range and record automatically the KHL heights as a function of frequency and of time whereby more complete information was obtained than by methods previously used.

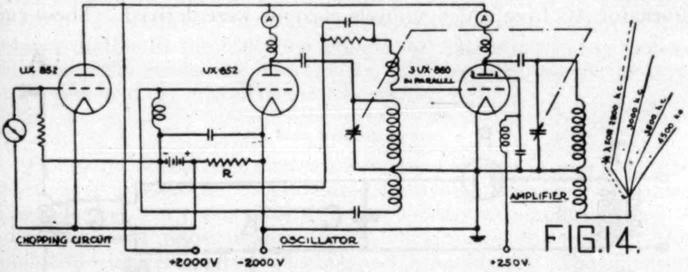

FIG. 14.

NEW METHOD OF USING CATHODE RAY TUBE FOR DETERMINING KHL HEIGHTS.

A new method of using a cathode ray tube for determining KHL heights was described in an article published in 1934 by Kirby, Berkner, Gilliland and Norton.[53] The received pulses were applied to one set of deflecting electrodes of a cathode ray tube. Sweep circuit voltages from a 60 cycle alternating voltage source were applied to the other set of deflecting electrodes. The pulses were shifted across the screen a known interval of time by means of a phase shifting bridge of the Turner and McNamara type.[54]

The rheostats in the bridge were calibrated directly in virtual heights. The method of operation involved first centering the directly received pulse on the screen. This was accomplished by an auxiliary bridge. Thereafter, the rheostats in the calibrated bridge were adjusted until the echo pulse under observation was centered. The KHL heights were then read directly from the calibrated dial.

KHL MEASUREMENTS IN POLAR REGIONS BY BONTCH-BRUEWITCH.

The system devised by Bontch-Bruewitch [55] for KHL measurements deserves especial mention because it was used at Murmansk, U.S.S.R., under polar expeditionary conditions. The circuit diagram of the transmitter is shown in Fig. 15. A power supply from a 1,000 cycle alternator was applied through transformer T and rectifier R to a small capacitor C. The capacitor was charged to 20 to 30 kilovolts and discharged through a rotary spark gap K into the anode circuit of a pair of 150 watt tubes. The tubes supplied pulses of carrier frequencies to the antenna A. The pulses were of 0.0002 second duration followed by intervals of 0.02 second. The rotary spark gap was illuminated by a small arc to produce regular sparking.

The motor M, which drove the rotary gap, also drove a small alternator AG from which 50 cycle currents were derived. These currents were applied through a phase splitter circuit P to the deflecting electrodes of a cathode ray tube CRT to produce a circular movement of the ray spot. The receiver consisted of a superheterodyne including one high frequency amplifier, two intermediate frequency amplifiers, and one low frequency amplifier. The output of the low frequency amplifier was applied to deflect the cathode ray from its circular path. Satisfactory measurements of the KHL heights were obtained for waves of 75 and 110 meters.

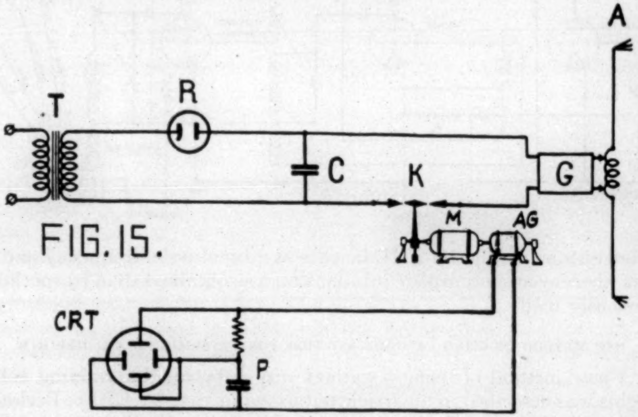

FIG. 15.

OTHER KHL DEVICES WERE DESCRIBED IN 1934.

An article by Verman, Char, and Mohammed [56] gives, in addition to a complete description of the pulse generator, transmitter, and pulse indicator, which the authors used in South India, a number of references to KHL recorders described by other experimenters. In their article Berkner and Wells [57] describe a KHL height measuring and recording device which was placed in operation at Huancayo in Peru.

DEVELOPMENTS OF 1935 TO 1943.

Most of the published developments of the years 1935 to 1943 consist of improvements in the previously recited methods of determining distance as a function of radio wave propagation time. It is more than probable that the present notes do not include many important advances which were unpublished because of wartime restrictions in the latter half of the period. In any event the present section is based largely upon the United States patents which issued on applications filed in the years 1935 to 1943. It is convenient to consider the patents with respect to their subject matter in the following groups: (*a*) phase measuring devices, (*b*) pulse echo measuring instruments, (*c*) frequency modulation type altimeters, and (*d*) miscellaneous devices.

(a) Phase Measuring Devices.

Hollman[58] discloses a distance measuring system in which an ultra short wave transmitter is modulated by a high frequency generator. The high frequency generator develops a constant amplitude wave of adjustable and determinable length. The ultra short wave, thus modulated, is received after reflection and demodulated. The amplitude of the demodulated wave is indicated. The modulator wave-length is adjusted until it passes from one maximum to the next maximum or from one minimum to the next minimum. These anti-nodes and nodes are produced by the "standing modulation waves." The distance of the wave reflecting object is then determined by the equation:

$$D = \frac{\lambda_1\lambda_2}{2(\lambda_1 - \lambda_2)},$$

where D = distance and λ_1 and λ_2 equal the two modulation wave-lengths.

Heising[59] describes an altimeter in which ultra short waves are radiated from a pair of dipole antennas spaced a half wave along one wing tip. These antennas may be considered as one antenna midway between the pair. The radiated waves are received after reflection by a second pair of dipole antennas also spaced a half wave apart on the other wing tip. The difference in the path lengths of the reflected waves produces a phase difference which is a function of altitude. For altitudes above about 300 feet, the ultra short waves are modulated by longer waves. The components from which the relative phase of the longer waves is determined, are derived from the modulation without affecting the ultra short wave phase determinations.

Alexanderson, Patterson, and Nickle[60] propose to radiate two carriers of different frequency which are modulated by a single low frequency. Thus two standing wave patterns will be established. The amplitudes or phases of the standing wave patterns are compared to indicate the distance of the reflecting surface. In one arrangement one of the transmitted carriers is adjusted in frequency until the amplitudes of the standing waves are equal. The receiver consists of a pair of superheterodyne receivers, respectively tuned to the carriers. The dial controlling the adjustable frequency carrier may be calibrated in units of distance.

Crosby[61] utilizes a system in which the phase of the directly radiated frequency modulated wave is compared with the phase of the reflected waves to indicate distance. In one species the direct and reflected waves are applied to a frequency discriminator and hence to a detector. The output of the detector indicates distance. In another device the output of the detector is applied to the reactance tube which frequency modulates the transmitter. A meter in the output circuit of the reactance tube is calibrated to indicate distance.

Budenbom,[62] in a patent entitled "Radio Directional and Distance Indicating System," proposes to measure distances within less than a wave-length of a transmitter by observing the relative time phase of the electric and magnetic components of the so called "induction field." The field at the antenna is made up of an electric component which has a 90° time phase relation to the magnetic component. These components are of the same time phase at about one wave-length and of intermediate phase at intermediate distances.

(b) Pulse Echo Measuring Instruments.

Smith[63] describes a pulse echo device in which the transmitter is keyed by a first commutator. A second commutator is driven in synchronism with the first commutator. The second commutator applies a direct current to charge a capacitor which is shunted by a resistor. The discharge of the capacitor is used to sweep a cathode ray across a distance scale. Thus the zero of the scale and the keying of the transmitter coincide. The received signals deflect the cathode ray at right angles to the distance scale.

V. 19

A "Radio Contourmeter" is described in a patent to Hunter.[64] A pair of antennas are arranged to radiate waves downwardly in advance of the aircraft carrying the device, and directly downwardly. The antennas are energized by a pair of transmitters which are keyed by two relaxation oscillators. The relaxation oscillators also provide sweep voltages for a dual gun cathode ray tube. The sweep from one gun is keyed off when the reflected wave is received to indicate the distance to the ground in advance of the craft. The sweep from the other gun is keyed off to indicate the altitude. Thus the altitude and the distance to the surface which the aircraft is approaching are indicated side by side by the cathode ray traces on the screen of the dual tube.

Lyman, Moseley and Hunter[65] describe two forms of pulse echo altimeters. One altimeter employs a synchronously operated commutator and a generator. The commutator keys the transmitter; the generator provides currents from which a rotating field is applied to deflect circularly a cathode ray beam. The beam is normally biased off; received echo signals overcome the bias and thereby the ray leaves a spot on the screen of the cathode ray tube. The angular position of the spot indicates the altitude.

The other device uses a relaxation oscillator which pulses the transmitter and synchronously applies deflecting voltages to a cathode ray tube. The ray is thus swept upwardly with its zero position corresponding to the outgoing pulse. The cathode ray is biased off when the reflected wave is received and is applied to the control grid of the tube. Thus the height of the sweep indicates altitude.

(c) Frequency Modulation Type Altimeters.

Numerous difficulties are encountered in the practical application of frequency modulation type altimeters. In these altimeters the beat frequency, i.e., the difference in frequency of the outgoing and reflected waves, is a measure of the altitude. The frequency is usually determined by "counting" the number of reversals per second of the beat frequency currents. Since the counting circuit is unable to distinguish between the fundamental frequency and harmonics, it is found that harmonics of appreciable amplitude cause false altitude indications. Carrier amplitude variations are another source of error. Variations in the terrain may introduce false readings. A fast moving airplane may establish frequency variations which modify the indications. There are other sources of error as will appear from the description of the patents in this section.

Newhouse [66] points out the desirability of employing a suitable amplifier for the beat frequency signals: Low frequencies correspond to low altitudes where the reflected signal strength may be large; while high frequencies correspond to high altitudes where the reflected signal strength may be small. Therefore, it is desirable to use a beat frequency amplifier with low gain for low frequencies and high gain for high frequencies. Moreover, the patentee states that some of the troublesome harmonic frequencies will be eliminated by choosing suitable operating parameters. By way of example for measuring distances between 20 feet and 5,000 feet the following apply: a frequency sweep of 25 megacycles, a carrier of 450 megacycles, a frequency of modulation of 80 cycles per second, and an amplification increasing approximately 6 decibels per octave increase in beat-note frequency, which extends from 160 to 40,000 cycles per second.

Lane and Newhouse [67] found that a beat frequency amplifier having a gain increasing with frequency solved some harmonic troubles but introduced others. This was due to the ease with which the higher frequency harmonics were amplified at very low altitudes. The proposed solution was to include an automatic feedback control circuit in the beat frequency amplifier. The feedback control circuit was of the degenerative type and was operated by deriving a voltage proportional to the beat frequency. This voltage was applied to increase the degenerative control and hence to level out the beat frequency amplifier gain for frequencies above that corresponding approximately to the altitude being measured. Thus the combination of an amplifier having a gain characteristic increasing with frequency and a degenerative control having a response dependent upon frequency offered an improvement in the frequency modulation type altimeter but introduced a difficulty which will be next considered.

Higgins and Newhouse [68] discovered that a temporary loss of signal and hence an excessive of control voltage may be applied to the automatically controlled degenerative feedback circuit of Lane and Newhouse.[67] This might cause the feedback amplifier to exert maximum degenerative control at the very time when higher beat frequency amplifier gain is required. Moreover, the restoration of normal signals might fail to restore the bias control and the altimeter circuit would remain "locked out of operation." The patentees propose to prevent "lock-out" by inserting an anti-lock-out circuit from which controlling voltages are applied to the degenerative amplifier circuit during loss of signals.

Sanders [69] demonstrates that a beat frequency type altimeter includes inherent errors when operated over a perfect reflecting surface. These errors prevail throughout the range but are most troublesome at low altitudes. He proposes to average out the errors by employing a variable frequency modulation band instead of the constant band used in the earlier frequency modulation altimeters. Several devices for obtaining a variable modulation band are described in the Sanders patent.

Guanella [70] offers several species of frequency modulation type altimeters in which means are provided for selecting the desired frequency components, for eliminating the undesired frequency components, and for reducing amplitude variation. Reference is made to the patent for a detailed discussion of the several species and their modes of operation.

In another patent of Sanders [71] it is proposed to average out the fixed errors by adding phase modulation to the frequency modulation of a beat frequency altimeter. The phase modulation is operated through a phase shifting range which is sufficient to balance out the fixed errors. The phase modulation may be produced by a motor driven "trombone" type of inductor.

Lane [72] discloses the following improvement in the counter circuit of a beat frequency altimeter: A diode tube is connected in the grid circuit of the amplifier preceding the counter. The diode is connected so as to have no effect when positive charges are applied to the amplifier grid; upon application of negative charges the diode offers a low impedance. The low impedance of the diode prevents negative charges from blocking the amplifier during fading of the echo signals. Thus an improvement in altitude indications is obtained.

Wolff and Sanders [73] describe a type of beat frequency altimeter in which a feedback path controls the modulation band width in the following manner: The power for energizing a "plunger" type motor for driving the variable capacitor in the oscillator circuit of the transmitter is derived through an amplifier connected to a local generator. The amplifier gain is controlled by a voltage derived from the counter circuit, so that, as the altitude increases, the power applied through the amplifier to the driving motor decreases, and thereby the capacity variation decreases. Thus, as the altitude increases, the modulation band decreases. This effectively increases the useful range of the altimeter because the signal to noise ratio improves with decreasing band width. In this arrangement the altitude may be indicated as a function of the voltage measured across the terminals of the motor driving the variable capacitor.

Alford,[74] noting that perfect sawtooth modulation would produce linear altitude indications, describes means for eliminating the non-linear portion caused by the "turning points" in the modulation characteristic. The non-linear portions or turning points of the modulation period may be eliminated according to the patent by blocking the transmitter or the receiver during these periods.

Chaffee [75] discloses several species of beat frequency altimeters. In one species the upper and lower sideband components are separated at the transmitter. One sideband is applied directly to the detector or mixing tube; the other sideband is applied after reflection. The combined sidebands are amplified, limited, and applied to a frequency conversion circuit. The output of the conversion circuit is an amplitude modulated current. The amplitude modulated current is demodulated, passed through a selective network (to eliminate unwanted frequencies), rectified, and applied to a direct current meter to indicate altitude. Other species are described in the patent.

In another patent, Newhouse [76] discloses an altimeter in which the transmission antenna is shielded from the reception antenna. The currents from the transmitter are applied through an adjustable delay network and a current limiter to the receiver detector. The reflected wave is received, amplified, limited and applied to the detector. The circuit following the detector is conventional. Adjustments of the delay network may be used to vary the range of the altimeter. The advantage of eliminating amplitude variations is that noise and other unwanted components may be "wiped off" the reflected carrier.

Varela [77] describes an altimeter beat frequency amplifier including an attenuator tube which is made inoperative in the absence of low frequency signals so that the full gain of the amplifier is realized. When low frequency beats are present, the attenuator tube becomes operative to reduce the high frequency gain of the amplifier.

(d) Miscellaneous Devices.

Before concluding this section, in which we are considering some of the developments of the years 1935 to 1943, some mention should be made of the devices which utilize reflected radio waves for measuring velocity instead of distance. Rice [78] makes use of the Doppler principle by noting the difference between the frequency of the wave transmitted from a moving airplane and the frequency of the same wave received on the airplane after reflection from the earth, and thus indicates the velocity of the airplane.

Gunn [79] also proposes to use the Doppler principle by transmitting a wave of frequency f from an aircraft transmitter. The wave is received at a relay station as $f \pm \Delta f$. The term Δf is established by the Doppler Effect. The frequency $f \pm \Delta f$ is changed to $n(f \pm \Delta f)$ and is relayed to the airplane where the frequency becomes $n(f \pm 2\Delta f)$. At the airplane the original frequency f is converted to nf. The two waves (nf and $n(f \pm 2\Delta f)$) are mixed so that the beat frequency $2\Delta f$ can be indicated. Since $2\Delta f$ is due to the Doppler Effect, the velocity of the airplane with respect to the relay station may be determined.

By using pulses of radio frequency energy, Gunn proposes to use the relay station to determine distance. The pulses are transmitted from the airplane, received at the relay station, delayed by a fixed amount, and relayed to the airplane receiver. The time t required for the pulses to make a round trip from the airplane to the relay station and back is determined. The delay constant y at the relay station is known. Hence the distance D may be determined from the equation

$$D = \frac{c(t - y)}{2},$$

where c = the velocity of propagation.

Hershberger [80] discloses a system for locating a wave reflecting object with respect to a pair of radiation patterns and for measuring the distance from the point of transmission to the object. A pair of directive antennas are alternately energized to establish fields on either side of a reference plane. The reflected pulses are applied to a cathode ray indicator to deflect the ray at right angles to the distance scale. Two distance scales, having the usual distance sweeps, are established by biasing the ray to the right and left (or up and down) in synchronism with the radiation. Thus the pair of sweeps and the signals impressed thereon indicate the distance and direction of the wave reflecting objects.

Budenbom [81] describes a beat frequency altimeter which is used in conjunction with a relay station to provide altitude indications and distance indications. Since the altitude will generally be less than the distance, the frequency of the beat note currents of the altimeter will be lower and therefore may be filtered from the currents of higher frequency which indicate distance. Thus the receiver is provided with a low pass filter and a high pass filter to separate the currents indicating respectively altitude and distance. "Singing" through the relay station is avoided by applying the received altimeter signals to modulate a fixed

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frequency carrier. The altimeter signals, modulating the carrier, are derived by demodulating the retransmitted signals after they are received on the aircraft carrying the altimeter. Thus the two components are made available to indicate altitude and distance to the relay station.

SUMMARY.

The foregoing notes trace the history of the measurement of the propagation times of radio waves as a means for determining distance. While the reader may feel that undue emphasis has been placed upon the KHL height measurements, a survey of the literature will show that only a small proportion of the reported observations have been cited here. Out of the hundreds of published articles on KHL height measurements, the writer has endeavored to select those which present the step-by-step improvements in the methods and apparatus. In the period just prior to the War, the United States Patents offered the principal means for tracing the development of the art. In the war period the notes are necessarily incomplete because of the scarcity of publications; this is no doubt due to secrecy conditions.

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THE NEW MICROSCOPES.

A DISCUSSION BY

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It is, to speak conservatively, of extreme interest to review the recent progress made by the scientist in his endeavor to penetrate the unseen world of the minute and disease-causing organisms, in particular a world of viruses—suspected, yet lying just beyond the scope of human vision and the power of the microscope to reveal; for the laboratory research worker, the doctor, the technician long have been familiar with the effects of these unseen enemies they have been called upon to treat and to cope with in man, animal, and plant, and while their knowledge of the infinitesimal has been growing steadily, they were, until very recently, unable to make the slight step "beyond" which would enable them to "see." But today, Science is exploring—looking for the first time upon totally new worlds through the eyes of totally new types of microscopes, microscopes new in principle of construction and in principle of illumination.

THE ELECTRON MICROSCOPE.

One of these new instruments, the Electron Microscope, has received considerable attention and is now being used extensively in both industrial and medical research. Based on the principles of geometric electron optics, this microscope utilizes electrons as a source of illumination instead of the light source of the ordinary light microscope.

Electrons, practically speaking, are the smallest, lightest particles of matter and electricity. Like light, they behave like corpuscles guided by waves. Unlike light, however, they travel in a straight line in a vacuum where, subject to the action of electric and magnetic fields, their behavior coincides with the laws and principles set down by Sir William Hamilton who, more than a century ago, demonstrated the existence of a close analogy between the path of a light ray through refracting media and that of a particle through conservative fields of force.

We know that these negatively-charged particles, the electrons, revolving about in their various orbits in the atom, serve to maintain the balance of the atom while the nucleus exerts the "positive" force which holds it together; and we also know that when this balance is upset, due to gain or loss of electrons, we think of the atom as "charged," since it is this circumstance which causes the tiny particle to attract or repel other electrons according to the state of its unbalance. And Science has succeeded in unbalancing the atoms to such an appreciable extent that the negative electricity may be withdrawn and harnessed for use in such instruments as the Electron Microscopes.

The fact has long been established that atoms are in a constant state of vibration in a heated body and that the greater the heat of the body, the greater the agitation of the atoms. According to the electron theory of metals, electrons circulate about a three-dimensional network, or lattice, of positive ions, some of the electrons being comparatively free, that is to say, the attractions of the ions are practically cancelled by the repulsions of the other electrons. It does not necessarily follow, however, that the same electrons consistently remain free. They may be controlled by the ions eventually, but regardless of this, there is always a fixed number of them that are free. Moreover, there is a critical value of speed above which the electrons are able to rise in metals and thus escape from their restraining positive charges, though at ordinary temperatures the proportion of them moving rapidly enough to do this is relatively small. However, as the heat applied to the metal is increased, not only is the thermal agitation of the electrons increased also, but the proportion among them possessing sufficiently high speeds to enable them to leave the metal.

Thus is heat applied to the electron source of the Electron Microscope which, in the case of most instruments of this kind, is a tungsten filament surrounded by a guard cylinder. After leaving the filament, or cathode, the electrons enter an electric field wherein are large accumulations of charge which serve to steadily speed up the motion of these freely-moving particles. Since the electrons travel in vacua, none of the kinetic energy gained in crossing the field is lost, the total kinetic energy, or energy of motion, gained in passing through this region being proportional to the voltage applied. We may deduce, therefore, that since increase of charge in an electric field means a proportional increase of kinetic energy of these electrons, the higher the voltage applied, the greater the speed of the electrons—all of which has been calculated mathematically and confirmed experimentally.

After traversing the electric field and passing through the anode, the electrons are concentrated on the specimen under examination by the first of three magnetic fields which are created by currents flowing through coils enclosed in soft iron shields, molded so as to concentrate the magnetic fields on a short section of the microscope's axis. Whereas in the ordinary light microscope glass lenses serve as the refractive media through which light rays are deflected, in the Electron Microscope it is these magnetic fields of rotational symmetry which are the refractive media and serve as the "lenses" which deflect the beams of electrons. The first of these, the condenser lens coil, corresponding to the substage condenser of the ordinary light microscope, concentrates the beam of electrons upon the specimen. The convergence of the beam falling on the specimen is controlled by varying the current through this condenser lens. Now, having passed through the specimen, the objective coil, similar in effect to the objective lens, focuses the electrons, and an intermediate image enlarged about one hundred diameters is formed. Finally, the projection coil, corresponding to the projection lens or ocular, produces a further magnified image on a large fluorescent screen. In some of the Electron Microscopes, there is a periscope-like attachment by means of which it is possible to locate and adjust for study the most interesting portion of the specimen, or that which it is desired should be examined, before the projection lens coil forms the final magnified image upon the screen, since it is sometimes difficult to accomplish this at high magnification. Also, if it is desired that a photographic record be made, the screen can be removed and a photographic plate substituted.

The specimen itself is supported on a thin nitrocellulose membrane less than one-millionth of an inch thick, and clamped in the tip of a cartridge which is inserted between the pole pieces of the objective coil. The membrane is suspended across the opening of a fine mesh screen, and a plate, serving as the movable stage, supports the cartridge. The image is projected onto the screen according to the density and atomic weight of the specimen. In other words, whereas in the ordinary light microscope the image is seen due to refraction of the specimen or differences in absorption, in the Electron Microscope the image is seen due to scattering of the electrons, and since electrons travel in a straight line in a vacuum, it stands to reason that even a fairly thin specimen will prove sufficient to deflect such particles. Electrons which strike a thick or solid portion of the specimen will, of course, not continue on in a straight line to the screen but will be either completely absorbed by the specimen or scattered too far out of the beam, thus failing to enter the narrow aperture of the objective, so that that portion of the screen corresponding to the thick portion of the specimen will remain dark. However, those electrons which are able to escape complete absorption or too great deflection because they do not happen to come in contact with too solid a portion of the specimen and either pass along on all sides of it or penetrate the thinner portions where it is possible they may encounter only a single heavy nucleus for considerable scattering (the angle of deflection being proportional to the square root of the thickness), continue on to the screen where they impinge and cause the chemically-treated screen to fluoresce, thus providing a study in light and shadow. If the atoms of a particular substance are heavy, they will also deflect more electrons than if they were light. It may be readily seen, therefore, that the thinner the specimen and its mounting, or the greater the variations in density of the specimen, the more internal structure and detail which may be seen, since too great density tends to absorb or interrupt the straight-line progress of too many of the electrons.

Focusing of the image is accomplished by varying the strength of the fields and thereby altering the focal length of the "lens" coils at will, so that the need of changing the specimen's position in relation to a fixed optical system as would be the case with an ordinary light microscope, is avoided. Thus, magnification in an Electron Microscope can be continuously varied.

Some specimens may be mounted directly on the fine mesh screen while others may be embedded in collodion, sealed between films of collodion, or suspended in a gelatin film, itself supported on collodion film. The supporting films beside being very thin must be homogeneous lest an artefact be created. For the most part, no staining of bacteriological specimens is done since usually they exhibit sufficiently high contrast in density to readily reveal flagella and other detail without any preparation except that of suspending the specimen in distilled water or other liquid and allowing a drop of the suspension to dry on the film surface which method is also utilized for specimens of colloidal particles, pigments, and other chemical preparations. At times, however, as Dr. L. Marton of Stanford University has mentioned in his article on the Electron Microscope (written for *The Journal of Bacteriology*, March 1941, when he was associated with the R. C. A. Research Laboratories), virus particles may show decided low contrast. One method which Dr. Marton mentioned for overcoming this is to secure a number of electron micrographs at various focuses and simply select the best one for study. Or the virus may be permitted to absorb colloidal gold which would result in an image of high contrast. Dr. Marton points out that there may be future need for a staining in density and that already osmic acid has been tried and used for this purpose.

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In this microscope, voltages of between 30,000 and 60,000 are used. It has been previously stated that the higher the voltage, the greater the speed of the electrons. This might now be augmented to read, the higher the voltage, the greater the speed of electrons; hence, the shorter the wavelength. An explanation of this may be approached through a brief discussion of short-wave diffraction as considered by Dr. Karl K. Darrow of Bell Laboratories in his book, "The Renaissance of Physics." In order to obtain convenient angles of refraction with the ordinary diffraction grating, it is necessary that the wavelengths of light be smaller, but not many times smaller, than the spacing between the wires or grooves. Naturally, a limit of measurement is reached in the region of ultra-violet light since it is impossible to further lessen the spacing of these gratings. However, this limitation was overcome when von Laue conceived the idea of substituting a crystal for an artificial grating since the atoms in a crystal are a thousand times more closely set together than are the wires or grooves of a grating and are arranged in precise regular order or "lattices," and, like gratings, are unable to diffract waves which are longer than the spacings between their atoms. Von Laue suggested that if a beam of light were directed across a crystal and made to strike a photographic plate, there would appear a spray of narrow rays each composed of a single wave train instead of the broad fan-like arrangement of the grating, and a pattern of star-like spots where the rays come in contact with the plate instead of the dark irregular blot when a grating is used. Of course, the rays are disposed according to the spacings of the atoms in the lattice and according to the character of the lattice. Von Laue confirmed this idea for waves short enough to be so diffracted and then advanced the theory that this principle might hold true for x-rays as well, which theory was almost immediately confirmed by Friedrich and Knipping. Shortly after Schroedinger began to develop De Broglie's wave theory of electrons, Elsasser conceived the idea that possibly these tiny particles might also be diffracted by crystals, and Doctors Davisson and Germer of the Bell Telephone Research Laboratories, using as part of their apparatus an electron gun, set out to test and to prove this theory. Due to their experiments and those of G. P. Thomson, it was established beyond a doubt that electron beams are diffracted just as are x-ray beams. However, it was also demonstrated in the course of these experiments that electrons of slow speeds and feeble kinetic energies are unable to penetrate the crystals. It was Thomson who utilized faster electrons and demonstrated that not only are electrons diffracted like x-rays, but like x-rays also they make an imprint upon a photographic plate at increased speeds. These three men, together with others, then measured the wavelengths which they compared with the momenta of these electrons by their diffraction. To these experiments and measurements were then applied the following Rules of Correlation: "Energy (E) is proportional to frequency (v), and momentum (p) is inversely proportional to wavelength (lambda), the same constant (h) appearing in both relations. (Frequency is interpreted as the velocity (V) of the waves divided by their wavelength.)" These Rules can be applied mathematically to the Electron Microscope to better illustrate the principles of its operation. In making use of the first Rule, however, it is necessary to substitute "voltage" for "frequency," and in so doing, therefore, the Rules of Correlation explain the increase of energy in relation to the increase of voltage as well as the increase of speed of electrons in relation to the decrease or shortening of wavelength when we say—the higher the voltage, the greater the speed; hence, the shorter the wavelength of electrons. It is interesting to note in passing that a 150-volt electron has a wavelength of one angstrom unit, this being more than 10^{-3} times smaller than the wavelength of visible or ultra-violet light.

Because the wavelengths utilized in an Electron Microscope are so much shorter than those employed in an ordinary light microscope, it is possible to obtain greatly increased resolution and magnification. As a matter of fact, resolution up to 20,000 or 25,000 diameters may be realized, and increased magnifications beyond this point up to 100,000, even 200,000 diameters, can be obtained, such magnifications, however, constituting enlargement of the image. (Definitions of "Resolution" and "Magnification" discussed under "The Ordinary Microscope.") This high magnification is greatly desirable since otherwise the eye would be unable to distinguish the fine detail of internal structure at a resolution of the order of 25,000. As a result of this increase in resolution and magnification over that of the ordinary light microscope which is between 1,600 and 2,500 diameters and in the ultra microscope between 2,500 and 5,000 diameters, many surface cells and much intricate internal structure hitherto unsuspected, or at least undetected by ordinary microscopes, have been revealed. To cite a few examples:

The streptococcal cells appear, not as individual cells, that is, separate and apart from one another, but as chain-like groups, the cells in each chain being bound together apparently by the strong rigid membrane or outer cellular wall which extends over a number of these cells and which is so plainly evident under the Electron Microscope. Subjected to sonic vibration, these cells suffer a loss of protoplasmic material from their interior, causing them to become mere "ghost" cells, which makes them more transparent to electron beams. That there exists considerable difference between the surface structure and internal composition of these cells has also been determined and demonstrated.

Using the Electron Microscope, Dr. Harry E. Morton of the Department of Bacteriology of the University of Pennsylvania Medical School and Dr. Thomas F. Anderson of R. C. A. Research Laboratories were able to demonstrate that in at least one instance where chemical reaction is induced by bacteria this reaction takes place "inside" the cells. The fact that diphtheria bacilli reduce potassium tellurite to metallic tellurium has been known for some time, but whether this reaction occurred inside the cell or on the cell surface or both had never been definitely shown until the Electron Microscope was made available. Then, securing unstained preparations of Corynebacterium diphtheriae grown on blood infusion agar, Drs. Morton and Anderson demonstrated that the typical polar granules appear as dense spherical masses, or possibly plates, of a very black color and that in unstained preparations of this same Corynebacterium diphtheriae grown on potassium tellurite chocolate agar, not only the polar granules are in evidence but also the tiny needle-like crystals inside the cell which disappear along with the black color of the cell masses when a drop of bromine water is added to 1 cc. of a suspension of the cells on potassium tellurite chocolate agar.

From this the experimenters were able to deduce that tellurium metal occurs in the form of needles and is the cause of the black color, and that this reaction occurs within the cells since the crystals have never been observed to lie totally outside the cell wall, although at times there is some distortion of the wall.

The Electron Microscope also affords such study and observation as that carried out by Dr. W. M. Stanley of the Rockefeller Institute for Medical Research and Dr. Thomas F. Anderson in their recent investigation of plant viruses. By means of electronmicrographs, they were able to judge the exact manner and extent of attack made on the tobacco mosaic virus by the protein antibodies in the blood stream of rabbits in which an artificial immunity to the virus had been produced.

Structures like that of the spirochete of Weil's disease, typhoid flagella, unusual internal structure of pertussis organisms, tubercle bacilli, the isolation and recognition of the influenza virus, the spores of trychophyton mentagrophytes, spirochaeta pallida with its accompanying flaggelar appendages, and colloidal particles are but a few of the interesting revelations of the Electron Microscope for medical science. Industrial science, too, has found this new research tool of great value in the study of metals, alloys, and plastics, as well as in the study of size, shape, and distribution of particles in chemical compounds and elements.

The Electron Microscope herein described is that manufactured by the Radio Corporation of America. There are, of course, variations in construction of the different instruments of this kind but all types are built along similar lines and upon the same general principles. In the Electron Microscope there is some aberration plus the additional disadvantages of having the specimen in a vacuum, not to mention the probable protoplasmic changes induced by the terrific bombardment of electrons, and finally, what is perhaps the greatest disadvantage insofar as medical science is concerned—that of being unable to view living organisms. Nevertheless, the disadvantages of the microscope are far overshadowed by its increased resolving and magnification powers which have combined to make it an invaluable research tool.

RESOLUTION AND MAGNIFICATION OF ORDINARY MICROSCOPE.

We have stated that the resolving power of the ordinary light microscope is restricted to between 1,600 and 2,500 diameters and that of the ordinary ultra microscope to between 2,500 and 5,000 diameters, resolution in any microscope being the ability of the instrument to reveal the most minute of component parts of a specimen so that each may be seen as a distinct and separate image. For instance, let us suppose an object is examined through which run two very fine parallel lines closely set together. If the two lines are visible under the microscope and are revealed as two separate images, then, apparently, no limit of resolution has been reached; but if the two lines are merged or revealed as only one, and upon further magnification the image merely becomes enlarged without separation of the lines, then a limit of resolution apparently has been reached and additional magnification would constitute only enlargement. Assuming now that the object is a point object in which case the images of the points would be diffraction disks, the disks should likewise be sufficiently resolved so that each may be distinguished as a single image. If, when these disks are seen to overlap, additional magnification fails to extend the distance between them, their size simply increasing in proportion to the increase of magnification, or, if they are all but completely merged and the image becomes just a spurious disk of light, it is evident that a definite limit of resolution has been attained and that further magnification would be useless. Resolution, in a broad sense, then, is the ability of the microscope to bring out or reveal internal structure and detail of a specimen, the shortest distance it is possible to separate two component parts, according to Abbe, being not less than the wavelength of light by which the specimen is illuminated divided by the numerical aperture of the objective lens plus the numerical aperture of the condenser lens, or, about one-third the wavelength of light utilized.

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The several factors which are generally acknowledged to be responsible for the limitation of resolving power are inter-related. Now when light passes from one medium into another of different density, in the instance which we are considering that of light refracted by the specimen and passing from air into glass, the light rays are deviated from their straight-line course; that is to say, that when they come to within a very short distance of this denser medium, they are acted upon by a very powerful force in such a manner that they execute a short rapidly curving motion, or an angle, and are pulled into the medium of greater density. When the rays of light undergo such a force, the momentum of the corpuscles is increased and the speed of the waves decreased, resulting, of course, in a shortening of the wavelengths. Here, again, we may make use of the second of the Rules of Correlation —"Momentum (of corpuscles) varies inversely as wavelength (of waves)." Once well inside the new medium, however, the light rays straighten themselves out again (unless the medium is so constructed that it possesses gradation of density in which case they follow a curved path). They do this in spite of the fact that the same forces are still acting upon them, although now these forces issue from all sides of them and so cancel each other out, the momentum of the photons or light corpuscles continuing to increase while the speed of the waves is proportionately retarded. If the light is refracted normally to the surface, however, it does not bend, but tends to cause a shortening of the optical path although the wavelength is shortened regardless. It is only when it is refracted obliquely to the surface that the light is bent, the greater being the obliquity of the incident ray and the denser the medium, the greater the bending of the angle of the cone of light and the shorter the wavelength. It might therefore seem desirable to obtain as great an angle of refraction as possible. However, shortening of the wavelength is not in exact proportion to the amount of bending except in the case of the diffraction grating. And regardless of how great a change there is in its angle, the numerical aperture of the light, or angular aperture as it is more properly called, remains constant.

In order, then, that the cone of light be large enough to supply the aperture of the objective with sufficient light to produce an accurate, bright, and enlarged image of the specimen, it is first necessary that the specimen be refracting or emitting light of an adequate quantity, since both magnification and resolution are largely dependent upon the amount of light which the objective utilizes and receives into the tube of the microscope and since such light as the objective does receive should be only that emitted by the specimen. It is obvious, therefore, that it is of primary importance for the specimen itself to be amply illuminated. This would seem to depend entirely on the actual light source, yet no matter how powerful a light source is employed, it is of little avail unless the condenser is of sufficient quality and aperture dimensions to accommodate the light which it receives from the source. If, for instance, the numerical aperture of the objective is 1.25, the width of the cone of light emanating from the specimen should completely fill this aperture in order for the fullest powers of the microscope to be realized. Now, since the condenser supplies the light to the specimen, it stands to reason that it, also, should have a numerical aperture of at least 1.25. However, if the condenser and specimen slide are separated by air, the condenser can provide light of only 1.00 N. A. to the specimen since, according to a law of optics, no aperture greater than 1.00 N. A., (this being the refractive index of air), can pass from a denser medium into air. To remedy this situation, an immersion fluid is placed between the top of the condenser and the lower side of the specimen slide as well as between the specimen and the objective lens.

Since no optical medium has an index of refraction greater than three and no immersion fluid an index of refraction greater than 1.7, to further increase resolving power, then, might it not be feasible to widen the apertures of the objective and condenser lenses, thus affording additional illumination for utilization by both specimen and objective? This idea would be entirely practical except for the fact that such enlargement of the lenses would increase aberration, both spherical and chromatic, and apparently present-day lenses are now as highly corrected as it is possible for human ingenuity and skillful workmanship to make them. Spherical aberration, caused by the paraxial rays coming to a focus at the center of the lens before those rays near the principal axis, is corrected by using concave and convex lenses of different material and, consequently, of different refractive index. In this manner spherical aberration of a convex lens, for instance, can be overcome, without its converging action being altered, by adding to the optical system a concave lens in which there is an equal and opposite aberration. Chromatic aberration, occurring when more than one wavelength of light is used to illuminate the specimen, is due to the fact that the shortest waves of the spectrum are refracted most and the longest waves least, thus causing the blue-violet waves to come to a focus ahead of the red waves and resulting in a series of colored foci all along the axis. Now since, as we have said, the shortening of the different groups of wavelengths is not in exact proportion to their bending and since this circumstance varies according to the substance the light rays pass through, it is possible to combine lenses or lens systems in such a way that white light may be obtained. For instance, a small concave flint-glass prism produces the same amount of dispersion as a large convex crown-glass prism. Thus, if these two prisms are placed with their edges opposite, the crown glass will bring together the spectrum produced by the flint glass and white light will be the result. However, the rays of white light will not extend parallel with the original direction but will bend toward the base of the crown glass since the mean refraction of the crown glass is greater than that of the flint glass. Achromatic objectives, corrected spherically for one color, chromatically for two; semi-apochromatic objectives, possessing moderate refractive indices and very small dispersion, in which a lens of fluorite is substituted for one of the glass lenses; apochromatic objectives, corrected spherically for two colors, chromatically for three; and also certain monochromatic lenses for use with light of one wavelength only are available for overcoming, at least in part, one of the conditions which tends to interfere with better resolution. Condensers, also, can be corrected for both spherical and chromatic aberration and must be achromatic-aplanatic if the light which enters the objective is to come only from the specimen, for condensers with spherical and chromatic aberration are unable to direct their entire cone of light upon the specimen.

In addition to being as highly corrected as possible and possessing a large numerical aperture, an objective should also be capable of adequately magnifying the image, being aided in this by the ocular which also serves at times to compensate for the defects in chromatic magnification which cannot be managed conveniently by high-power objectives, the magnification of the final image being the product of the magnification of the objective multiplied by the magnification of the ocular. An amplifier is sometimes inserted between the objective and ocular which causes the rays of light from the objective to diverge to a greater extent, thus doubling the size of the image. Magnification may also be improved by increasing the tube length, by increasing the distance from which the image is projected, and by altering the positions of the various lenses in an adjustable objective. In general, the greater the magnification, the smaller will be the specimen field, but, as has been stressed, high powers of magnification should always be accompanied by equally high powers of resolution.

As we have seen, resolution in the ordinary light microscope is definitely restricted by a number of inter-related elements. Even when monochromatic light is employed, there is always present some spherical aberration with which to contend. True, better visibility of specimens is provided by dark-field microscopy in which the specimen is viewed by the high contrast of its own scattered or reflected light against a dark field, although in this type of illumination objects in the field must be well separated. Much fine detail and brilliant color of specimens can be observed by means of the polarization of light. Further, it is possible to illuminate the specimen with shorter and shorter wavelengths of light, the shorter the wavelength of light used, the more of the fine detail of the specimen which can be seen, but a limit is reached here, also, for ordinary glass lenses are not transparent to ultra-violet rays. However, in the ultra-violet microscope, having a resolution twice that of the instruments using "visible light," the condenser, objective, and ocular are all made of quartz and, by substituting the photographic plate for direct observation, many excellent micrographs of numerous varieties of organisms and cellular structures can be made. But when viewed directly, nothing of the nature or structure of the specimen can be ascertained; only the light scattered by the specimen is distinguishable, the size of the specimen being roughly estimated by the amount of light refracted.

These seemingly unsurmountable obstacles of the ordinary microscopes would appear to indicate that Abbe's law and the contention of physicists that "any object which is smaller than one-half the wavelength of light by which it is illuminated cannot be seen in its true form or detail" are destined to remain undefied.

REDUCTION IN THEORETICAL LIMIT OF RESOLUTION DEMONSTRATED.

But Dr. Francis F. Lucas of the Bell Telephone Research Laboratories and Doctors Louis Caryl Graton and E. C. Dane, Jr., of the Department of Geology, Harvard University, have very convincingly demonstrated a reduction in these theoretical limits of resolution and visibility with their instruments, designed for use in the visible light region of the spectrum.

The Graton-Dane microscope is mounted on a 360 kg. steel foundation bed which, in turn, is supported by six rubber-in-sheer marine-engine mountings—this for the purpose of eliminating all vibration and insuring stability of parts, two factors upon which both men have laid great stress. Any type source, such as the carbon arc, metallic arc, incandescent filament, Point-O-Lite, Mercury Vapor, or any of the special forms of monochromators, can be used for illuminating the specimen with direct and dark-field transmitted, vertical and oblique reflected, or polarized light. The image beam itself follows a straight-line path in passing from the objective, the objective ranging anywhere from the shortest to the greatest in working distance, through the tube to the ocular, as few lenses as possible being placed in its way. The spiral-cut rack and pinion which moves the stage and sub-stage assembly in longitudinal tracks or guides can be operated by hand or by an electric motor and is independent of the fine adjustment, also motor-driven, which moves only the objective and the carriage carrying the objective. Whereas manual operation of the fine adjustment which is one hundred times more sensitive than that of the ordinary instruments necessitates five hundred turns of the knob to move the objective a distance of but one millimeter, (an adjustment calculated to require a time period of twenty-five minutes), by means of the motor it is possible to move the objective at the rate of 0.01 mm. per second or 0.004 mm. per second, depending upon which of the two speeds is desired, rapid motion being used when the image appears considerably out of focus and decreased speed being used when the image seems to be reaching a point of perfection.

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Resolution up to 6,000 diameters and magnification up to 50,000 diameters have been achieved with this high precision microscope which photographs or enables observation of both opaque and transparent preparations; in fact, polishing scratches measuring, in width, but one-tenth the wavelength of light used have been clearly distinguished. It is the opinion of both Dr. Graton and Dr. Dane that some present-day lenses are really capable of better resolution than claimed for them by their manufacturers, it having been their experience to use objectives exhibiting superior qualities of resolution over those of identical medium and numerical aperture, proving that not only have already available lenses surpassed their theoretical limits of resolution, indicating that it might be possible to design objectives with still greater numerical apertures, but that the accepted theory regarding this resolution is sadly in need of revision. Dr. Lucas's microscope utilizing an objective with a numerical aperture of 1.60, for instance, in combination with monohromnaphalene immersion fluid, also yields resolution up to 6,000 diameters being, like the Graton-Dane scope, a high precision instrument constructed with the idea of maintaining absolute stability of parts. Dr. Lucas also has expressed doubt as to the complete validity of the generally accepted theory of resolution.

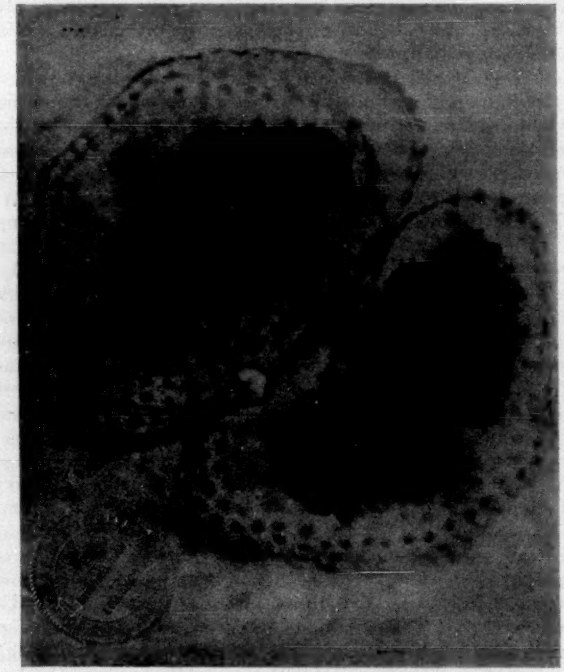
In working with a high precision ultra-violet micro-camera, into which a tri-color filter system has been incorporated, which he has just recently perfected, Dr. Lucas is able to obtain a minimum magnification of 30,000 diameters and a maximum magnification of 60,000 diameters. With this instrument it is possible to view living cells and organisms, no staining or killing of organisms being necessary, and Dr. Lucas has succeeded in obtaining excellent photomicrographs (both still and motion pictures). Of special significance to industry, for instance, is the ability of this scope to demonstrate the size, shape, and reactions in motion and affinity of the tiny particles of which rubber is composed under varying conditions of temperature, etc., while its ability to reveal living rat and mouse sarcoma and carcinoma cells and to demonstrate the development and behavior of the syphilitic organism is of far more than average interest to medical science.

England's Dr. J. E. Barnard has succeeded in obtaining resolution up to 7,500 diameters with his ultra-dark-field scope in which he uses a combined illuminator. In this, an outer system of glass acts as the immersion dark-field illuminator while the inner immersion system of quartz makes possible the passage of a transmitted beam of light through the specimen. Both condensers have the same focus, one for visible light, the other for ultra-violet radiation, and both can be stopped out at will. When, for instance, bacteria are being observed, immersion contact is made between the condenser and quartz slide, the dark-field illuminator being used, thus revealing the bacteria with visible light. When the dark-field illuminator is closed, however, a beam of ultra-violet light may be directed up through the quartz condenser and focused on the bacteria. The object-glass, of course, has to be adjusted since it does not possess the same focus for ultra-violet that it does for visible light. Staining of specimens is thus unnecessary, making it possible to secure photomicrographs of living minute organisms.

In addition to these four microscopes, a fourth, belonging to the Canadian Department of Mines and located at Ottawa, and almost identical in principle and construction to that of Doctors Dane and Graton, has demonstrated ability to attain equally high resolution. This, like the scopes of Doctors Dane, Graton, and Lucas, is fitted with a tube for visual observation although intended mainly for microphotographical work in the field of metallurgy. It is Dr. Graton's belief, however, that his instrument and that of Dr. Dane might also be adaptable to the purposes of biological research. Referring, in the description of their "Precision, All Purpose Microcamera" (*Journal of the Optical Society of America*), to the necessity or "desirability" of "reëxamining the classical conception of the limit of useful magnification," Doctors Dane and Graton have this to say:

"So long as the makers accepted the conventional limit as valid and had already attained it, there was little incentive toward progress. But with that limit apparently surpassed, there is no present knowledge as to how far ahead the true limit may lie. If present-day objectives do substantially better than the 'limit' for which they were designed, is it not reasonable to suppose that effort to do better still may conceivably be rewarded?"

To such an inquiry there can be but one logical answer—an agreement which, while perhaps not concurred in by all, must, for those stimulated to more intense interest and effort by the possibilities of uncovering new facts, pose further questions; for, if the improvement of one part results in the improved performance of the whole, is it not also reasonable to suppose that additional changes of additional parts, yes, even changes with respect to principle and method might likewise bear fruit?



Chlorophyl Cell (algae) (The Universal Microscope). 17,000× on 35 mm. film.

THE UNIVERSAL MICROSCOPE.

It is not only a reasonable supposition, but already, in one instance, a very successful and highly commendable achievement on the part of Dr. Royal Raymond Rife of San Diego, California, who, for many years, has built and worked with light microscopes which far surpass the theoretical limitations of the ordinary variety of instrument, all the Rife scopes possessing superior ability to attain high magnification with accompanying high resolution. The largest and most powerful of these, the Universal Microscope, developed in 1933, consists of 5,682 parts and is so-called because of its adaptability in all fields of microscopical work, being fully equipped with separate substage condenser units for transmitted and monochromatic beam, dark-field, polarized, and slit-ultra illumination, including also a special device for crystallography. The entire optical system of lenses and prisms as well as the illuminating units are made of block-crystal quartz, quartz being especially transparent to ultra-violet radiations.

The illuminating unit used for examining the filterable forms of disease organisms contains fourteen lenses and prisms, three of which are in the high-intensity incandescent lamp, four in the Risley prism, and seven in the achromatic condenser which, incidentally, has a numerical aperture of 1.40. Between the source of light and the specimen are subtended two circular, wedge-shaped, block-crystal quartz prisms for the purpose of polarizing the light passing through the specimen, polarization being the practical application of the theory that light waves vibrate in all planes perpendicular to the direction in which they are propagated. Therefore, when light comes into contact with a polarizing prism, it is divided or split into two beams, one of which is refracted to such an extent that it is reflected to the side of the prism without, of course, passing through the prism while the second ray, bent considerably less, is thus enabled to pass through the prism to illuminate the specimen. When the quartz prisms on the Universal Microscope, which may be rotated with vernier control through 360 degrees, are rotated in opposite directions, they serve to bend the transmitted beams of light at variable angles of incidence while, at the same time, a spectrum is projected up into the axis of the microscope, or rather a small portion of a spectrum since only a part of a band of color is visible at any one time. However, it is possible to proceed in this way from one end of the spectrum to the other, going all the way from the infra-red to the ultra-violet. Now, when that portion of the spectrum is reached in which both the organism and the color band vibrate in exact accord, one with the other, a definite characteristic spectrum is emitted by the organism. In the case of the filter-passing form of the Bacillus Typhosus, for instance, a blue spectrum is emitted and the plane of polarization deviated plus 4.8 degrees. The predominating chemical constituents of the organism are next ascertained after which the quartz prisms are adjusted or set, by means of vernier control, to minus 4.8 degrees (again in the case of the filter-passing form of the Bacillus Typhosus) so that the opposite angle of refraction may be obtained. A monochromatic beam of light, corresponding exactly to the frequency of the organism (for Dr. Rife has found that each disease organism responds to and has a definite and distinct wavelength, a fact confirmed by British medical research workers), is then sent up through the specimen and the direct transmitted light, thus enabling the observer to view the organism stained in its true chemical color and revealing its own individual structure in a field which is brilliant with light.

The objectives used on the Universal Microscope are a 1.12 dry lens, a 1.16 water immersion, a 1.18 oil immersion, and a 1.25 oil immersion. The rays of light refracted by the specimen enter the objective and are then carried up the tube in parallel rays through twenty-one light bends to the ocular, a tolerance of less than one wavelength of visible light only being permitted in the core beam, or chief ray, of illumination. Now, instead of the light rays starting up the tube in a parallel fashion, tending to converge as they rise higher and finally crossing each other, arriving at the ocular separated by considerable distance as would be the case with an ordinary microscope, in the Universal tube the rays also start their rise parallel to each other but, just as they are about to cross, a specially-designed quartz prism is inserted which serves to pull them out parallel again, another prism being inserted each time the rays are about ready to cross. These prisms, inserted in the tube, which are adjusted and held in alignment by micrometer screws of one hundred threads to the inch in special tracks made of magnelium (magnelium having the closest coefficient of expansion of any metal to quartz), are separated by a distance of only thirty millimeters. Thus, the greatest distance that the image in the Universal is projected through any one media, either quartz or air, is thirty millimeters instead of the 160, 180, or 190 millimeters as in the empty or air-filled tube of an ordinary microscope, the total distance which the light rays travel zig-zag fashion through the Universal tube being 449 millimeters, although the physical length of the tube itself is 229 millimeters. It will be recalled, that if one pierces a black strip of paper or cardboard with the point of a needle and then brings the card up close to the eye so that the hole is in the optic axis, a small brilliantly-lighted object will appear larger and clearer, revealing more fine detail, than if it were viewed from the same distance without the assistance of the card. This is explained by the fact that the beam of light passing through the card is very narrow, the rays entering the eye, therefore, being practically parallel, whereas without the card the beam of light is much wider and the diffusion circles much larger. It is this principle of parallel rays in the Universal Microscope and the resultant shortening of projection distance between any two blocks or prisms plus the fact that objectives can thus be substituted for oculars, these "oculars" being three matched pairs of ten-millimeter, seven-millimeter, and four-millimeter objectives in short mounts, which make possible not only the unusually high magnification

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and resolution but which serve to eliminate all distortion as well as all chromatic and spherical aberration.

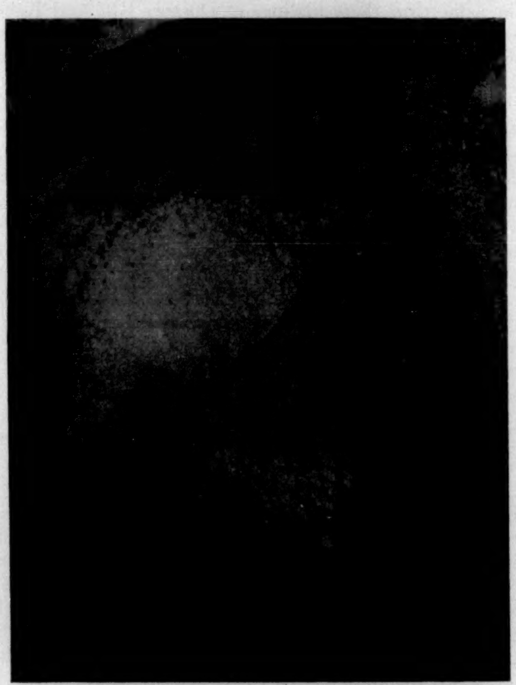
Quartz slides with especially thin quartz cover glasses are used when a tissue section or culture slant is examined, the tissue section itself also being very thin. An additional observational tube and ocular which yield a magnification of 1,800 diameters are provided so that that portion of the specimen which it is desired should be examined may be located and so that the observer can adjust himself more readily when viewing a section at a high magnification.

The Universal stage is a double rotating stage graduated through 360 degrees in quarter minute arc divisions, the upper segment carrying the mechanical stage having a movement of 40 degrees, the body assembly which can be moved horizontally over the condenser also having an angular tilt of 40 degrees plus or minus. Heavily-constructed joints and screw adjustments maintain rigidity of the microscope which weighs two hundred pounds and stands twenty-four inches high, the bases of the scope being nickel cast-steel plates, accurately surfaced, and equipped with three leveling screws and two spirit levels set at angles of 90 degrees. The coarse adjustment, a block thread screw with forty threads to the inch, slides in a one and one-half dovetail which gibs directly onto the pillar post. The weight of the quadruple nosepiece and the objective system is taken care of by the intermediate adjustment at the top of the body tube. The stage, in conjunction with a hydraulic lift, acts as a lever in operating the fine adjustment. A six-gauge screw having a hundred threads to the inch is worked through a gland into a hollow, glycerine-filled post, the glycerine being displaced and replaced at will as the screw is turned clockwise or anticlockwise, allowing a five-to-one ratio on the lead screw. This, accordingly, assures complete absence of drag and inertia. The fine adjustment being seven hundred times more sensitive than that of ordinary microscopes, the length of time required to focus the Universal ranges up to one hour and a half which, while on first consideration, may seem a disadvantage, is after all but a slight inconvenience when compared with the many years of research and the hundreds of thousands of dollars spent and being spent in an effort to isolate and to look upon disease-causing organisms in their true form.

Working together back in 1931 and using one of the smaller Rife Microscopes having a magnification and resolution of 17,000 diameters, Dr. Rife and Dr. Arthur Isaac Kendall of the Department of Bacteriology of Northwestern University Medical School were able to observe and demonstrate the presence of the filter-passing forms of Bacillus Typhosus. An agar slant culture of the Rawlings strain of Bacillus Typhosus was first prepared by Dr. Kendall and inoculated into six cubic centimeters of "Kendall" K Medium, a medium rich in protein but poor in peptone and consisting of one hundred mg. of dried hog intestine and 6 cc. of tyrode solution (containing neither glucose nor glycerine) which mixture is shaken well so as to moisten the dried intestine powder and then sterilized in the autoclave, fifteen pounds for fifteen minutes, alterations of the medium being frequently necessary depending upon the requirements for different organisms. Now, after a period of eighteen hours in this K Medium, the culture was passed through a Berkefeld "N" filter, a drop of the filtrate being added to another six cubic centimeters of K Medium and incubated at 37 degrees centigrade. Forty-eight hours later this same process was repeated, the "N" filter again being used, after which it was noted that the culture no longer responded to peptone medium, growing now only in the protein medium. When again, within twenty-four hours, the culture was passed through a filter—the finest Berkefeld "W" filter, a drop of the filtrate was once more added to six cubic centimeters of K Medium and incubated at 37 degrees centigrade, a period of three days elapsing before the culture was transferred to K Medium and yet another three days before a new culture was prepared. Then, viewed under an ordinary microscope, these cultures were observed to be turbid and to reveal no bacilli whatsoever. When viewed by means of dark-field illumination and oil immersion lens, however, the presence of small, actively-motile granules was established, although nothing at all of their individual structure could be ascertained. Another period of four days was allowed to elapse before these cultures were transferred to K Medium and incubated at 37 degrees centigrade for twenty-four hours when they were then examined under the Rife Microscope where, as was mentioned earlier, the filterable typhoid bacilli, emitting a blue spectrum, caused the plane of polarization to be deviated plus 4.8 degrees. Then when the opposite angle of refraction was obtained by means of adjusting the polarizing prisms to minus 4.8 degrees and the cultures illuminated by a monochromatic beam coördinated in frequency with the chemical constituents of the typhoid bacillus, small, oval, actively-motile, bright turquoise-blue bodies were observed at a magnification of 5,000 diameters, in high contrast to the colorless and motionless debris of the medium. These observations were repeated eight times, the complete absence of these bodies in uninoculated control K Media also being noted.

To further confirm their findings, Doctors Rife and Kendall next examined eighteen-hour old cultures which had been inoculated into K Medium and incubated at 37 degrees centigrade, since it is just at this stage of growth in this medium and at this temperature that the cultures become filterable. And, just as had been anticipated, ordinary dark-field examination revealed unchanged, long, actively-motile bacilli; bacilli having granules within their substance; and free-swimming, actively-motile granules; while under the Rife Microscope were demonstrated the same long, unchanged, almost colorless bacilli; bacilli, practically colorless, inside and at one end of which was a turquoise-blue granule resembling the filterable forms of the typhoid bacillus; and free-swimming, small, oval, actively-motile, turquoise-blue granules. By transplanting the cultures of the filter-passing organisms or virus into a broth, they were seen to change over again into their original rod-like forms.

At the same time these findings of Doctors Rife and Kendall were confirmed by Dr. Edward C. Rosenow of the Mayo Foundation, the magnification with accompanying resolution of 8,000 diameters of the Rife Microscope, operated by Dr. Rife, was checked against a dark-field oil immersion scope operated by Dr. Kendall and an ordinary 2 mm. oil immersion objective, × 10 ocular, Zeiss scope operated by Dr. Rosenow at a magnification of 900 diameters. Examinations of gram and safranin stained films of cultures of Bacillus Typhosus, gram and safranin stained films of cultures of the streptococcus from poliomyelitis, and stained films of blood and of the sediment of the spinal fluid from a case of acute poliomyelitis were made with the result that bacilli, streptococci, erythrocytes, polymorphonuclear leukocytes, and lymphocytes measuring nine times the diameter of the same specimens observed under the Zeiss scope at a magnification and resolution of 900 diameters, were revealed with unusual clarity. Seen under the dark-field microscope were moving bodies presumed to be the filterable turquoise-blue bodies of the typhoid bacillus which, as Dr. Rosenow has declared in his report ("Observations on Filter-Passing Forms of Eberthella Typhi—Bacillus Typhosus—and of the Streptococcus from Poliomyelitis," Proceedings of the Staff Meetings of the Mayo Clinic, July 13, 1932), were so "unmistakably demonstrated" with the Rife Microscope, while under the Zeiss scope stained and hanging drop preparations of clouded filtrate cultures were found to be uniformly negative. With the Rife Microscope also were demonstrated brownish-gray cocci and diplococci in hanging drop preparations of the filtrates of streptococcus from poliomyelitis. These cocci and diplococci, similar in size and shape to those seen in the cultures although of more uniform intensity, and characteristic of the medium in which they had been cultivated, were surrounded by a clear halo about twice the width of that at the margins of the debris and of the Bacillus Typhosus. Stained films of filtrates and filtrate sediments examined under the Zeiss microscope, and hanging drop, dark-field preparations revealed no organisms, however. Brownish-gray cocci and diplococci of the exact same size and density as those observed in the filtrates of the streptococcus cultures were also revealed in hanging drop preparations of the virus of poliomyelitis under the Rife Microscope, while no organisms at all could be seen in either the stained films of filtrates and filtrate sediments examined with the Zeiss scope nor in hanging drop preparations examined by means of the dark-field. Again using the Rife Microscope at a magnification of 8,000 diameters, numerous nonmotile cocci and diplococci of a bright-to-pale pink in color were seen in hanging drop preparations of filtrates of Herpes encephalitic virus. Although these were observed to be comparatively smaller than the cocci and diplococci of the streptococcus and poliomyelitic viruses, they were shown to be of fairly even density, size, and form and surrounded by a halo. Again, both the dark-field and Zeiss scopes failed to reveal any organisms, and none of the three microscopes disclosed the presence of such diplococci in hanging drop preparations of the filtrate of a normal rabbit brain. Dr. Rosenow has since revealed these organisms with the ordinary microscope at a magnification of 1,000 diameters by means of his special staining method and with the Electron Microscope at a magnification of 12,000 diameters. Dr. Rosenow has expressed the opinion that the



Tetanus Spores (The Universal Microscope). 25,000× on 35 mm. film, enlarged 227,000×.

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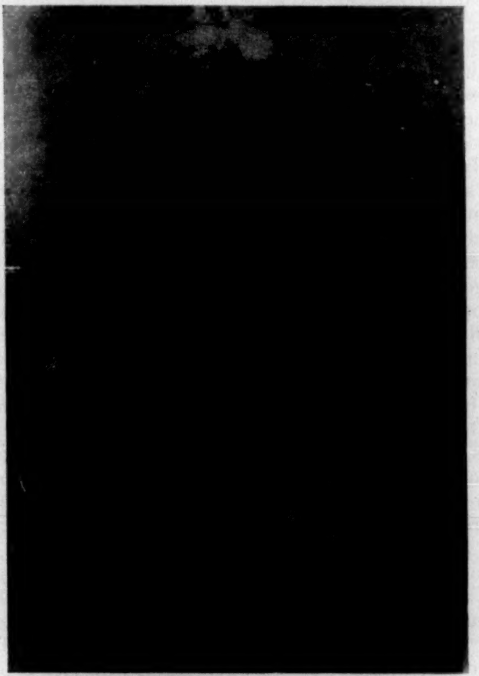
inability to see these and other similarly revealed organisms is due, not necessarily to the minuteness of the organisms, but rather to the fact that they are of a non-staining, hyaline structure. Results with the Rife Microscopes, he thinks, are due to the "ingenious methods employed rather than to excessively high magnification." He has declared also, in the report mentioned previously, that "Examination under the Rife Microscope of specimens containing objects visible with the ordinary microscope, leaves no doubt of the accurate visualization of objects or particulate matter by direct observation at the extremely high magnification obtained with this instrument."

Exceedingly high powers of magnification with accompanying high powers of resolution may be realized with all of the Rife Microscopes one of which, having magnification and resolution up to 18,000 diameters, is now being used at the British School of Tropical Medicine in England. In a recent demonstration of another of the smaller Rife scopes (May 16th, 1942) before a group of doctors including Dr. J. H. Renner of Santa Barbara, California; Dr. Roger A. Schmidt of San Francisco, California; Dr. Lois Bronson Slade of Alameda, California; Dr. Lucile B. Larkin of Bellingham, Washington; Dr. E. F. Larkin of Bellingham, Washington; and Dr. W. J. Gier of San Diego, California, a Zeiss ruled grading was examined, first under an ordinary commercial microscope equipped with a 1.8 high dry lens and × 10 ocular, and then under the Rife Microscope. Whereas fifty lines were revealed with the commercial instrument and considerable aberration, both chromatic and spherical noted, only five lines were seen with the Rife scope, these five lines being so highly magnified that they occupied the entire field, without any aberration whatsoever being apparent. Dr. Renner, in a discussion of his observations, stated that "The entire field to its very edges and across the center had a uniform clearness that was *not* true in the conventional instrument." Following the examination of the grading, an ordinary unstained blood film was observed under the same two microscopes. In this instance, one hundred cells were seen to spread throughout the field of the commercial instrument while but ten cells filled the field of the Rife scope.

The Universal Microscope, of course, is the most powerful Rife scope, possessing a resolution of 31,000 diameters and magnification of 60,000 diameters. With this it is possible to view the interior of the "pin point" cells, those cells situated between the normal tissue cells and just visible under the ordinary microscope, and to observe the smaller cells which compose the interior of these pin point cells. When one of these smaller cells is magnified, still smaller cells are seen within its structure. And when one of the still smaller cells, in its turn, is magnified, it, too, is seen to be composed of smaller cells. Each of the sixteen times this process of magnification and resolution can be repeated, it is demonstrated that there are smaller cells within the smaller cells, a fact which amply testifies as to the magnification and resolving power obtainable with the Universal Microscope.

More than 20,000 laboratory cultures of carcinoma, were grown and studied over a period of seven years by Dr. Rife and his assistants in what, at the time, appeared to be a fruitless effort to isolate the filter-passing form, or virus, which Dr. Rife believed to be present in this condition. Then, in 1932, the reactions in growth of bacterial cultures to light from the rare gasses was observed, indicating a new approach to the problem. Accordingly, blocks of tissue one-half centimeter square, taken from an unulcerated breast carcinoma, were placed in triple-sterilized K Medium and these cultures incubated at 37 degrees centigrade. When no results were forthcoming, the culture tubes were placed in a circular glass loop filled with argon gas to a pressure of fourteen millimeters, and a current of 5,000 volts applied for twenty-four hours, after which the tubes were placed in a two-inch water vacuum and incubated at 37 degrees centigrade for twenty-four hours. Using a specially designed 1.12 dry lens, equal in amplitude of magnification to the 2 mm. apochromatic oil immersion lens, the cultures were then examined under the Universal Microscope, at a magnification of 10,000 diameters, where very-much animated, purplish-red, filterable forms, measuring less than one-twentieth of a micron in dimension, were observed. Carried through fourteen transplants from K Medium to K Medium, this B. X. virus remained constant; inoculated into four hundred and twenty-six Albino rats, tumors "with all the true pathology of neoplastic tissue" were developed. Experiments conducted in the Rife Laboratories have established the fact that these characteristic diplococci are found in the blood monocytes in 92 per cent. of all cases of neoplastic diseases. It has also been demonstrated that the virus of cancer, like the viruses of other diseases, can be easily changed from one form to another by means of altering the media upon which it is grown. With the first change in media, the B. X. virus becomes considerably enlarged although its purplish-red color remains unchanged. Observation of the organism with an ordinary microscope is made possible by a second alteration of the media. A third change is undergone upon asparagus base media where the B. X. virus is transformed from its filterable state into cryptomyces pleomorphia fungi, these fungi being identical morphologically both macroscopically and microscopically to that of the orchid and of the mushroom. And yet a fourth change may be said to take place when this cryptomyces pleomorphia, permitted to stand as a stock culture for the period of metastasis, becomes the well-known mahogany-colored Bacillus Coli.

It is Dr. Rife's belief that all microörganisms fall into one of not more than ten individual groups (Dr. Rosenow has stated that some of the viruses belong to the group of the streptococcus) and that any alteration of artificial media or slight metabolic variation in tissues will induce an organism of one group to change over into any other organism included in that same group, it being possible, incidentally, to carry such changes in media or tissues to the point where the organisms fail to respond to standard laboratory methods of diagnosis. These changes can be made to take place in as short a period of time as forty-eight hours. For instance, by altering the media—four parts per million per volume—the pure culture of mahogany-colored Bacillus Coli becomes the turquoise-blue Bacillus Typhosus. Viruses or primordial cells of organisms which would ordinarily require an eight-week incubation period to attain their filterable state, have been shown to produce disease within three days' time, proving Dr. Rife's contention that the incubation period of a microörganism is really only a cycle of reversion. He states:



Typhoid Bacillus (The Universal Microscope). 23,000× on 35 mm. film, enlarged 300,000×.

"In reality, it is not the bacteria themselves that produce the disease, but we believe it is the chemical constituents of these micro-organisms enacting upon the unbalanced cell metabolism of the human body that in actuality produce the disease. We also believe if the metabolism of the human body is perfectly balanced or poised, it is susceptible to no disease."

In other words, the human body itself is chemical in nature, being comprised of many chemical elements which provide the media upon which the wealth of bacteria normally present in the human system feed. These bacteria are able to reproduce. They, too, are composed of chemicals. Therefore, if the media upon which they feed, in this instance the chemicals or some portion of the chemicals of the human body, becomes changed from the normal, it stands to reason that these same bacteria, or at least certain numbers of them, will also undergo a change chemically since they are now feeding upon a media which is not normal to them, perhaps being supplied with too much or too little of what they need to maintain a normal existence. They change, passing usually through several stages of growth, emerging finally as some entirely new entity—as different morphologically as are the caterpillar and the butterfly (to use an illustration given us). The majority of the viruses have been definitely revealed as living organisms, foreign organisms it is true, but which once were normal inhabitants of the human body—living entities of a chemical nature or composition.

Under the Universal Microscope disease organisms such as those of tuberculosis, cancer, sarcoma, streptococcus, typhoid, staphylococcus, leprosy, hoof and mouth disease, and others may be observed to succumb when exposed to certain lethal frequencies, coördinated with the particular frequencies peculiar to each individual organism, and directed upon them by rays covering a wide range of waves. By means of a camera attachment and a motion picture camera not built into the instrument, many "still" micrographs as well as hundreds of feet of motion picture film bear witness to the complete life cycles of numerous organisms. It should be emphasized, perhaps, that invariably the same organisms refract the same colors when stained by means of the monochromatic beam of illumination on the Universal Microscope, regardless of the media upon which they are grown. The virus of the Bacillus Typhosus is always a turquoise-blue, the Bacillus Coli always mahogany-colored, the Mycobacterium li prae always a ruby shade, the filter-passing form or virus of tuberculosis always an emerald green, the virus of cancer always a purplish-red, and so on. Thus, with the aid of this microscope, it is possible to reveal the typhoid organism, for instance, in the blood of a suspected typhoid patient four and five days before a Widal is positive. When it is desired to observe the flagella, of the typhoid organism, Hg salts are used as the media to see at a magnification of 10,000 diameters.

In the light of the amazing results obtainable with this Universal Microscope and its smaller brother-scopes, there can be no doubt of the ability of these instruments to actually reveal any and all micro-organisms according to their individual structure and chemical constituents.

With the aid of its new eyes—the new microscopes, all of which are continually being improved—Science has at last penetrated beyond the boundary of accepted theory and into the world of the viruses with the result that we can look forward to discovering new treatments and methods of combating the deadly organisms—for Science does not rest.

To Dr. Karl K. Darrow, Dr. John A. Kolmer, Dr. William P. Lang, Dr. L. Marton, Dr. J. H. Renner, Dr. Royal R. Rife, Dr. Edward C. Rosenow, Dr. Arthur W. Yale, and Dr. V. K. Zworykin, we wish to express our appreciation for the help and information so kindly given us and to express our gratitude, also, for the interest shown in this effort of bringing to the attention of more of the medical profession the possibilities offered by the new microscopes.

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AXIPETAL FORCE AND ACCELERATION.

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The apparatus to be described, Fig. 1, was designed for Laboratory and Lecture room use for classes in elementary physics, to provide means for investigating experimentally the laws governing the motion of a small mass in a circular path.

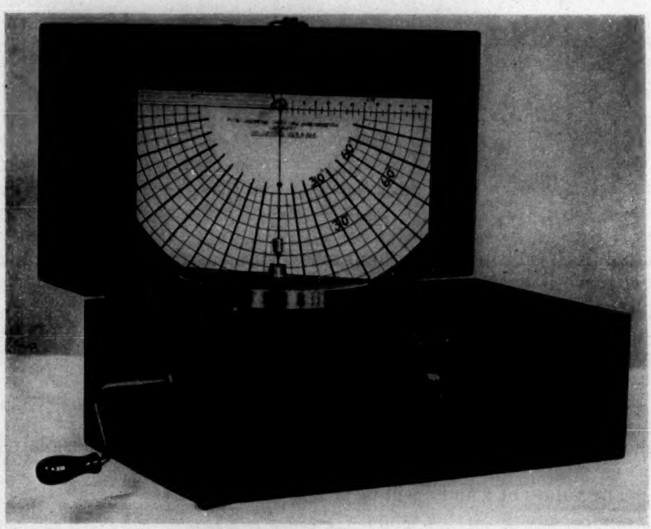

Fig. 1.

Figure 1 represents a conical pendulum with an imposed constant angular velocity about the axis of rotation. If the apparatus is placed on a horizontal table the axis of rotation will be vertical. The rotation of the turntable and board, which is maintained remarkably constant by a spring motor drive, can be set to values of R.P.M. from 60 to 110. The pendulum length can be quickly adjusted to from 7 to 13 cm., using the cm. scale on the board. The deflections of the pendulum, which reach values to 60°, can be read with ease to within 1° on the protractor on the rotating board. The pendulum weighs about 7 gms. The highest speed of rotation is 2 R.P.S., hence there is no danger from flying parts.

Referring to Fig. 2, the force mg acting on the bob is resolved into two components: one producing tension T in the string, and the radial component, the axipetal force

$$mg \tan \theta = T \sin \theta \tag{1}$$

from the center of gravity of the small bob B in the direction perpendicular to the axis of rotation and towards the axis. In Fig. 3 the

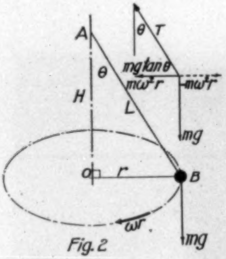

Fig. 2

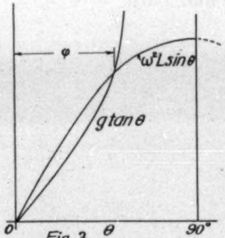

Fig. 3

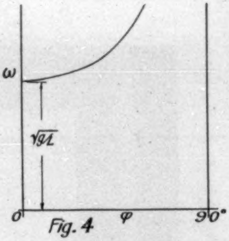

Fig. 4

radial force (1) is plotted for unit mass, with θ as abscissae. Note that this curve is independent of the angular velocity of the pendulum as well as of its length.

The radial force (1) produces the radial acceleration towards the axis which maintains the circular motion of radius r and angle θ. This acceleration is

$$\omega^2 r = \omega^2 L \sin \theta = (2\pi N/60)^2 L \sin \theta, \tag{2}$$

where N = R.P.M. (revolutions per min.). This acceleration is plotted in Fig. 3.

The values of θ and r will be steady if

$$mg \tan \theta = m\omega^2 L \sin \theta, \tag{3}$$

$$mg = m\omega^2 L \cos \theta = T \cos \theta. \tag{4}$$

Equation (3) states that the radial force is continuously equal to the acceleration produced times the mass in both value and direction (Newton's Second Law of Motion); they are equal vectors. If the right hand side of (3) be brought to the left, with a minus sign, shown as a dotted vector in Fig. 2, the force $- m\omega^2 L \sin \theta$ can be considered to be a fictitious inertia force reacting against the force towards the axis, and in equilibrium with it, or in equilibrium with mg and T. In this manner d'Alembert treated problems in dynamics by the method of statics.

Equation (4) indicates two possible equilibrium values of θ

$$\theta = 0 \qquad \text{and} \qquad \theta = \varphi = \cos^{-1} g/\omega^2 L \tag{5}$$

under the condition:

$$g/\omega^2 L < 1. \tag{6}$$

If $\omega^2 L < g$, then the curves, Fig. 3, will intersect at the origin only; if $\omega^2 L = g$, the curves will be tangent at the origin; if $\omega^2 L > g$, then the curves intersect at $\theta = 0$ and at $\theta = \varphi$, as given by (5). Note that between $\theta = 0$ and $\theta = \varphi$, $\omega^2 L \sin \theta$ is greater than $g \tan \theta$, and less for angles above φ. The pendulum starts deflecting as if an axifugal force were acting on the bob, till the balance indicated by (3) is attained. At this deflection the horizontal component of mg will be just large enough to maintain the bob in the circular path of radius r, Fig. 2. If the bob were placed at a greater radius and let go, the horizontal component of mg would be greater than necessary to maintain circular motion at that radius, and the bob would be brought back to the equilibrium value, after oscillations.

The motor speed regulator is set to give the Turntable a certain value of angular velocity ω. On releasing the stop the spring motor rotates the Turntable and board in clockwise direction, as seen from above, with an acceleration. When the angular velocity reaches the value $\omega = \sqrt{g/L}$, Fig. 4, the pendulum will begin to deflect as the speed increases above this value, and reaches a steady deflection, as the angular velocity attains its set value.

OPERATION.

No special skill is required to use this apparatus. The student adjusts the pendulum length to a large value, say 13 cm., and to a high speed for the motor, in order to obtain a large deflection to start with. He winds the motor. A few seconds after releasing the motor stop the motor will reach constant speed; the student counts the number of turns of the Turntable in one minute. The deflection of the pendulum is easily read, to within 1°, on the protractor carried by the rotating board. The experiment is repeated with a shorter pendulum, at same motor speed. At lower motor speed settings the procedure is repeated. Below 80 R.P.M. the deflections are too small.

The following table shows a set of readings and suggestive calculations. Column IV checks the observed deflections φ by the values calculated from the observed values of ω and L, eq. 5; and columns VII and VIII are calculated values of the equal forces, per unit mass, in (3), see Fig. 3.

Observations.			Calculations.				
I N R.P.M.	II L.	III φ.	IV $\cos^{-1} g/\omega^2 L$.	V ω.	VI $r = L \sin \varphi$.	VII $\omega^2 L \sin \varphi$.	VIII $g \tan \varphi$.
106	13	53°	52°	11.1	10.4 cm.	1,330	1,300
	12	49	48		8.92	1,100	1,086
	11	44	44		7.65	945	948
	10	39	39		6.29	775	793
	9	29	28		4.35	537	521
	8	20	21		2.74	337	335
98	13	44	44	10.25	9.5	1,000	948
	12	39	39		7.56	793	793
	11.5	36	36		6.66	700	711
	11	34	32		6.15	648	661
86	13	22	22	9	4.87	394	396
	12.5	13	14		2.81	228	226

We have used the terms axipetal and axifugal, and not centripetal and centrifugal. If a solid rotates, all its particles at any instant must rotate about an instantaneous (or permanent) axis; if the particles rotated about a point center they could not retain their relative distances apart, which they must if the body is to retain its form.

The above description and explanation should be sufficient for the use of the apparatus in classes in elementary physics.

In the following a closer study of the transient motion and oscillations of the pendulum, Fig. 1, will be made which may be of interest.

1. *The pendulum is assumed to be of infinite length*, and the Turntable to have reached constant angular velocity. This condition can be realized by placing the bob center on the line of intersection of the rotating horizontal turntable and of the plane of the board through the vertical axis of rotation, at the distance r from the axis and then letting go. For a small angular motion of the board ωt, the bob center moves, at the start, on the normal to the board, and hence tangent to the circle of radius r, through a distance $\omega r t$. There is a radial displacement Δr along the hypotenuse, away from the axis and along the board, away from the circular path of the original point of contact on the board:

$$\Delta r = [r^2 + (\omega r t)^2]^{1/2} - r = \tfrac{1}{2}\omega^2 r t^2, \tag{7}$$

which corresponds to an acceleration $\omega^2 r$ away from the axis. The equation of motion is

$$\frac{d^2 r}{dt^2} = \omega^2 r. \tag{8}$$

For $t = 0$, $r = r_0$ and $dr/dt = 0$, and

$$r = r_0/2[e^{\omega t} + e^{-\omega t}] \qquad \text{where} \qquad \omega t = \Omega, \tag{9}$$

which is a spiral motion, starting in the direction normal to the board and taking asymptotically the angle $\pi/4$ with the board as t increases.

If the bob be stopped at any distance $r = r_1$, the force which must be exerted, towards the axis after resisting a radial impulse due to the stopping of the radial velocity, will be

$$F = -m\omega^2 r_1 = m\frac{d^2r}{dt^2}.$$

The displacements towards the axis will be the same as the initial value in (7) of problem 1, but opposite in sign. In the circular motion the radial displacements continuously bring the bob from the tangent motion, which would take place if $F = 0$, to the circular path. No work is done. The radial displacements remain of the second order of infinitesimals with respect to the time, and hence with respect to the corresponding displacements on the circle, and their sum vanishes in a revolution, as t is taken closer to zero. But in (7), problem 1, the radial displacements accumulate and increase in value. Work is done on the bob; the work may be considered supplied entirely by the spring motor, while maintaining ω constant, or the motor may be considered inactive, and the work supplied by a slight change in the angular velocity of the Turntable.

2. *Same problem as 1, except that the bob is suspended from the axis by a string of finite length*, as in Fig. 1.

The work done on the pendulum, supplied entirely by the motor while maintaining ω constant, equals the energy, kinetic and potential, of the bob

$$\int T\omega dt = mv^2/2 + mgL(1 - \cos\theta), \tag{10}$$

where $v^2 = (\omega r)^2 + (Ld\theta/dt)^2$ and T is the torque or moment supplied by the motor.

The torque about the axis of rotation must equal the moment of acceleration times the mass of the bob (law of areas)

$$T = \frac{d}{dt} mr^2\omega. \tag{11}$$

Equation (10) becomes, after using (11) and differentiating,

$$L\frac{d^2\theta}{dt^2} = \omega^2 L \sin\theta\cos\theta - g\sin\theta. \tag{12}$$

For small values of θ, and $\omega^2 L < g$, the motion is oscillatory. For $\omega^2 L = g$ the bob is free to move on the sphere bottom of radius L.

Oscillations about $\theta = \varphi$.

The angular acceleration $d^2\theta/dt^2$ in (12) will be zero for two values of θ: zero and φ, which corresponds to (5). The angular velocity $d\theta/dt$

is constant at $\theta = \varphi$, and there is a point of inflection at this point of the θ, t curve.

Transferring (12) to the new origin $\theta = \varphi$, and dropping terms above the first order

$$L\frac{d^2\Delta}{dt^2} = \Delta\frac{d}{dt}[\omega^2 L \sin\theta\cos\theta - mg\sin\theta]_{\theta=\varphi}, \tag{13}$$

$$\frac{d^2\Delta}{dt^2} = -\Delta\omega^2\sin^2\varphi. \tag{14}$$

For small amplitudes the oscillations are sinusoidal about $\theta = \varphi$, and are responsible for the phenomenon called hunting, in a steam engine equipped with an axifugal ball governor.

The same equation (12) is obtained if it is assumed that the heavy Turntable, of moment of inertia I, at angular velocity ω_0 for $\theta = 0$, furnishes the energy to the bob.

The energy equation is

$$I\omega_0^2/2 = I\omega^2/2 + mv^2/2 + mgL(1 - \cos\theta). \tag{15}$$

The moments about the axis due to external forces is now zero, hence the angular momentum is constant

$$\frac{d}{dt}[I + mr^2]\omega = 0, \tag{16}$$

$$[I + mr^2]\omega = \text{constant} = I\omega_0. \tag{17}$$

Equation (12) is obtained from (15) and (17).

The period of oscillation about $\theta = \varphi$ is

$$T_\varphi = T/\sin\theta, \tag{18}$$

where

$$T = 2\pi\sqrt{\frac{L}{g}\cos\theta} = 2\pi\sqrt{\frac{H}{g}} \tag{19}$$

is the period of rotation of the cone pendulum.

In deriving eq. (12) it was assumed that ω was constant when the bob was released. The amplitude of oscillation, θ, is obtainable from

$$\cos\theta = 2\cos\varphi - 1, \tag{20}$$

which is derived by making $d\theta/dt = 0$ in (10).

In using the apparatus, Fig. 1, the pendulum starts deflecting as the angular velocity of the Turntable increases beyond the value $\omega = \sqrt{g/L}$; hence the amplitude of the oscillations is much less than indicated in (20). The oscillations are barely visible at medium deflections, and soon die out.

The center of the axipetal force and the center of gravity of the bob.

For a parallel system of forces acting on the particles of the bob, as would be caused by the attraction of the earth, the resultant force would pass through the c.g. of the bob. The resultant axipetal force would equal the value calculated by assuming all the particles concentrated at the c.g.; but the resultant force would not, in general, pass through the c.g. unless one of the principal axes of the inertia ellipsoid of the bob intersected the axis of rotation at right angles, and another principal axis were normal to the plane V passing through the c.g. of the bob and through the axis of rotation.

The axipetal forces are all perpendicular to the axis of rotation; they are radial in horizontal projection and form a fan to the right and left of the c.g. of the bob, hence their resultant must be perpendicular to the axis of rotation.

Consider plane V through the axis of rotation and c.g. to be the reference plane XOZ, and a plane H through c.g. and perpendicular to the axis of rotation to be YOX. The axipetal force components along the axes X, Y, and Z will be, eq. (2), and Figs. 1 and 2,

$$\begin{aligned} \Sigma f_x &= \Sigma m\omega^2 rx/r = \Sigma m\omega^2 x = M\omega^2\bar{x} \\ \Sigma f_y &= \Sigma m\omega^2 ry/r = \Sigma m\omega^2 y = M\omega^2\bar{y} = 0 \\ \Sigma f_z &= 0. \end{aligned} \tag{21}$$

From (21) the resultant axipetal force may be calculated in all cases as if the entire mass M of the bob were concentrated at the c.g., at the distance $\bar{r} = \bar{x} = L \sin \theta$ from the axis. This does not imply that the resultant force will pass through c.g. unless the moments of the forces f_x about the Y axis, and of the forces f_y about the X axis are both zero,

$$\begin{aligned} \Sigma f_x z &= \Sigma m\omega^2 xz = 0 \\ \Sigma f_y z &= \Sigma m\omega^2 yz = 0, \end{aligned} \tag{22}$$

which specify the positions mentioned for the principal axes of the inertia ellipsoid. For a bob of uniform density, and suspended at the top, the form would be that of a surface of revolution, with axis perpendicular to V, with the two equal principal axes longer than the third. A sphere would meet the conditions (22). Any form would be practical if the dimensions are small with respect to r.

Amplidyne Gives Extra Range to Gunfire Control and Speeds War Production.—The short circuit—often blamed for knocking out lights in homes and huge apparatus in power stations—is now increasing the maneuverability of guns on planes and ships and speeding the output of armor plate and other products of war industry.

The short circuit and a coil arrangement known as compensating field winding are features of a General Electric development, the amplidyne, a simple rotating unit which resembles a motor or generator. The device embodies magic similar to that found in the complex circuits of a radio set—namely the ability to pick up the small whispers of electric signals and magnify them instantly into powerful commands to large machines.

A typical amplidyne assignment is controlling guns in aircraft turrets. Although one man could not, by himself, maneuver guns against the terrific wind resistance encountered by a plane flying 400 miles an hour, with the amplidyne he controls fire power as deadly in the air as a machine gun battery on land and with the same ease as he would sight a rifle on a target range.

Already the amplidyne is in successful operation on fire control equipment aboard ships, on antiaircraft guns, and on searchlights both ashore and at sea. The device provides accurate, sturdy control and high speed of response over a wider range than other equipment and, because of its simple construction, is proving less vulnerable than other models to bomb impact and flying splinters from enemy shell fire. Simplicity of operation is also an important factor in installations aboard planes flying at high altitudes, where atmospheric conditions frequently impair the operation of other types of equipment.

The amplidyne is also used on the world's largest power shovel, making possible the stripping of nearly a million tons of earth a month from coal fields. By simplifying control and maintenance on hoists which bring coal from depths of several hundred feet, the amplidyne is also adding to the output of vertical coal mines.

In the steel industry, one of the first operations requires the loading of iron ore and other materials into blast furnaces. The amplidyne enabled one blast furnace skip hoist to produce 49,705 tons of pig iron a month—a world's record.

R. H. O.

A QUANTITATIVE STUDY OF THE LITHOSPHERE AND GRAVITY ANOMALIES ALONG THE ATLANTIC COAST.

BY

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ABSTRACT.

The principle of isobaric equilibrium is quantitatively applied to a strong lithosphere near a continental boundary. Following methods outlined in earlier papers, the deformation of the lithosphere near Cape Henry is determined from the magnitude and distribution of the sedimentary and fluid load superimposed on the original crystalline basement. From the calculated figure and the equivalent load, the resulting distribution of vertical stress and gravity defect are estimated. Except for the prediction of appreciable positive gravity defects at the continental shelf the calculated and observed gravity distributions are quite similar. The fibre stress due to the deformation is evaluated and it is shown that the position of the calculated maximum stress in tension on the landward side coincides with the observed position of lithospheric failure or the Fall Line. The strength in tension of the upper lithosphere here is shown to be less than 8.5×10^8 dynes/cm.^{2}. The simultaneous prediction of the approximate magnitudes of the gravity anomalies, their distribution and the location of the Fall Line appears to show that a strong elastic lithosphere characterized by the constant $b = 8.4 \pm 2 \times 10^{-8}$ cm.$^{-1}$ has a real and important geological existence. The investigation shows that due to the finite strength of the lithosphere, long linear areas parallel to continental coast lines are usually regions of disturbed gravity.

Geologists have long recognized that continental boundaries are regions of very great theoretical interest. The transition between typical continental and oceanic structures is characterized by systematic deformations of the lithosphere and by related peculiarities in the attraction of gravity. Such regions are especially valuable for the determination of the physical characteristics of the lithosphere through the study of the associated gravity anomalies. The subject of gravitational anomalies at the border of a continent has received wide attention. V. Meinesz [1] has remarked the occurrence of sudden algebraic increases in gravity anomaly in going from shallow to deep water and, moreover, notes that the space average of the negative anomaly may be notably greater than the adjacent positive anomalies. Some part of this latter phenomena is due to the coast anomaly studied by Helmert and by Schweydar [2] who showed that if the continent and ocean were in isostatic equilibrium, then the distribution of the gravity anomaly occasioned by the effects of topography is such that the negative anomaly is about three times as great as the positive anomaly. But, because

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[1] Advanced Report Comm. on Continental and Oceanic Structures, Am. Geophys. Union, Sept. 1939. *Proc. Amster. Acad.*, **44**, 883 (1941).

[2] W. Schweydar, *Zeit. f. Geophys.*, **2**, 148 (1926).

Schweydar's estimates lead to a distribution not much like that actually observed, it is thought that the finite strength of the lithosphere has a more important bearing on the actual distribution and therefore, this aspect of the problem will be considered here.

In a series of papers [3] the author has discussed the influence of a strong lithosphere on the anomalies of gravity and worked out basic methods for determining the deformations and stresses in the lithosphere due to various superposed loads. These methods permit for the first time a calculation of the gravity defects that accompany a given deformation and, further, enable one to estimate the fibre stress at any selected point. Because the problem of the gravity distribution near a coast line is of general interest, it appears worth while to apply these new methods to an idealized evaluation of the distribution of gravity defects in some coastal region where adequate data permit a comparison with observation. Before proceeding to a detailed analysis of a particular traverse, it is convenient to work out the deformation of the lithosphere due to various types of empirical load having direct application to geological problems. By superposing the solutions for loads having these arbitrary distributions it is practical to describe the actual deformation of the lithosphere for almost any specified load.

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DEFORMATION OF A UNIFORM LITHOSPHERE BY VARIOUS SUPERPOSED LOADS.

Consider a long coast line, and suppose that a section of the lithosphere of unit width and lying at right angles to this line be considered. Suppose that the distribution of some superposed load per unit area W is known as a function of the distance x as measured along the section. Then the vertical deformation y of the neutral axis of the section may be determined by finding solutions to the basic equation [3]

$$\frac{1}{4b_0^4}\frac{d^4y}{dx^4} + y = \frac{W}{d_0 g} = H, \tag{1}$$

where b_0, the basic constant of the lithosphere, may be determined by observation [3b] or may be calculated from

$$b_0^4 = \frac{d_0 g}{4EI}. \tag{2}$$

In this relation, d_0 is the density of the underlying weak magma, g is the acceleration due to gravity, E is the modulus of elasticity (assumed to be constant), I is the sectional moment of inertia per unit width of the effective beam, d is the density of the equivalent load W, while H is the total equivalent load height reduced to the same density as the underlying magma.

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[3] Ross Gunn: (*a*) JOURNAL OF THE FRANK. INST., **224**, 19 (1937). (*b*) JOURNAL OF THE FRANK. INST., **236**, 47 (1943). (*c*) JOURNAL OF THE FRANK. INST., **236**, 373 (1943).

Solutions to Eq. (1) are most easily obtained by evaluating Eq. (17) of reference 3*b* or

$$y = \int \frac{bW}{2d_0g}\epsilon^{-bz}(\cos bx + \sin bx)dx. \tag{3}$$

In general, y is evaluated for a given coördinate z measured parallel to x and its dependence on z determined.

It is convenient in most cases to employ the "reduced" load height H in place of W because this conveniently makes the "pseudo-isostatic" height [3c] coincide with the original undeformed surface. This, in turn, permits one to see by inspection the approximate position and magnitude of the accompanying gravity anomalies provided the geometries of the load and resulting deformed lithosphere are plotted to the same scale. The reduced load height H is defined by $H = W/d_0g = \dfrac{hd}{d_0}$ where h is the actual height of the load at any selected position, d is the actual density and d_0 is the density of the underlying magma. The following solutions are obtained from Eq. (3) but in order to differentiate clearly between deformations *under* and to the *side* of an impressed load, one employs q as the z coördinate for all points immediately under a load while p is used for all such points outside where H is zero.

In the following summary of useful results, (*a*) gives the assumed distribution of the load, (*b*) gives the resulting deformation y_0 of the lithosphere outside the load, and (*c*) gives the deformation y_u under the load.

Case I: Block Load. Width bG radians and reduced height H.

$$(a)\quad H = H_0, \tag{4}$$

$$(b)\quad y_0 = H_0\left[\frac{(1 - \epsilon^{-bG}\cos bG)}{2}\epsilon^{-bp}\cos bp + \frac{\epsilon^{-bG}\sin bG}{2}\epsilon^{-bp}\sin bp\right], \tag{5}$$

where p is measured away from the edge of the block.

$$(c)\quad y_u = H_0\left[1 - \epsilon^{-\frac{bG}{2}}\left(\cosh bq \cos bq \cos\frac{bG}{2} + \sinh bq \sin bq \sin\frac{bG}{2}\right)\right], \tag{6}$$

where q is measured from the center of the block. If desired, Eq. (19) of reference 3*b* may be employed in place of (*c*).

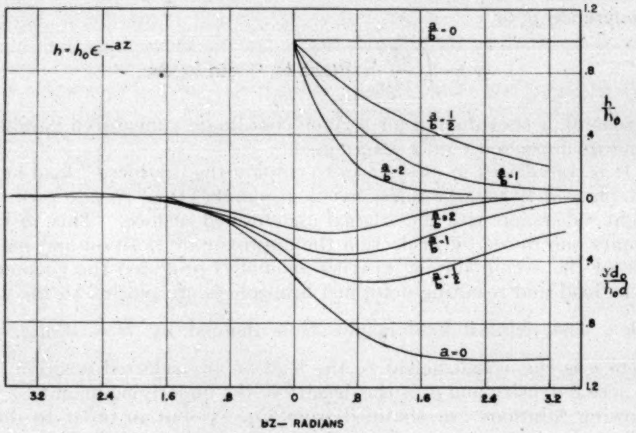

FIG. 1. Deformed figure of lithosphere for load defined by $h = h_0\epsilon^{-az}$.

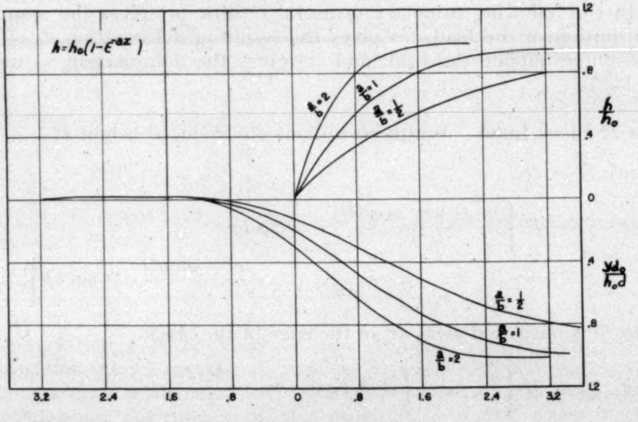

FIG. 2. Deformed figure of lithosphere for load defined by $h = h_0(1 - \epsilon^{-az})$.

Case II: Load with Logarithmic Distribution.

$$(a)\quad H = H_0\epsilon^{-az}, \tag{7}$$

$$(b)\quad y_0 = H_0\left[\frac{\epsilon^{-bp}[(ab + 2b^2)\cos bp + ab\sin bp]}{2[(a + b)^2 + b^2]}\right], \tag{8}$$

$$(c)\quad y_u = H_0\left[\frac{\epsilon^{-aq}}{1 + \frac{1}{4}\left(\frac{a}{b}\right)^4} + \frac{\epsilon^{-bq}[(ab - 2b^2)\cos bq + ab\sin bq]}{2[(b - a)^2 + b^2]}\right]. \tag{9}$$

The deformations for this useful case are plotted in Fig. 1 for various values of a/b.

Case III: Load with Block and Logarithmic Distribution.

$$(a)\quad H = H_0(1 - \epsilon^{-az}), \tag{10}$$

$$(b)\quad y_0 = H_0\left[\frac{\epsilon^{-bp}\cos bp}{2} - \frac{\epsilon^{-bp}[(ab + 2b^2)\cos bp + ab\sin bp]}{2[(a + b)^2 + b^2]}\right], \tag{11}$$

$$(c)\quad y_u = H_0\left[1 - \frac{\epsilon^{-bq}\cos bq}{2} - \frac{\epsilon^{-aq}}{1 + \frac{1}{4}\left(\frac{a}{b}\right)^4} - \frac{\epsilon^{-bq}[(ab - 2b^2)\cos bq + ab\sin bq]}{2[(b - a)^2 + b^2]}\right]. \tag{12}$$

The deformations for this case are given in Fig. 2.

Case IV: Load with Linear Distribution.

$$(a)\quad H = H_0\left(1 - \frac{z}{k}\right), \tag{13}$$

$$(b)\quad y_0 = H_0\left[\frac{1}{2}\epsilon^{-bp}\cos bp - \frac{\epsilon^{-bp}}{4bk}(\cos bp - \sin bp) + \frac{\epsilon^{-b(k+p)}}{4bk}(\cos b(k + p) - \sin b(k + p))\right] \quad \text{for } -\infty < p < 0, \tag{14}$$

$$(bb)\ y_0 = H_0\left[-\frac{1}{2}\epsilon^{-bp}\cos bp - \frac{\epsilon^{-bp}}{4bk}(\cos bp - \sin bp) + \frac{\epsilon^{-b(p-k)}}{4bk}(\cos b(p-k) - \sin b(p-k))\right]$$

$$\text{for}\quad k < p < +\infty, \quad (15)$$

$$(c)\ y_u = H_0\left[1 - \frac{bq}{bk} - \frac{1}{2}\epsilon^{-bq}\cos bq - \frac{\epsilon^{-bq}}{4bk}(\cos bq - \sin bq) + \frac{1}{4bk}\epsilon^{-b(k-q)}(\cos b(k-q) - \sin b(k-q))\right]$$

$$\text{for}\quad 0 < q < k. \quad (16)$$

The resulting distribution of deformation for this type of load is given in Fig. 3 for several values of *bk*. In addition to the above specific cases earlier communications have given the distribution for a single force, for a loaded thrust fault and for a logarithmic type mountain. Since almost any observed load may be broken down into sections described by combinations of the above distributions, the resulting deformation of the lithosphere may easily be evaluated.

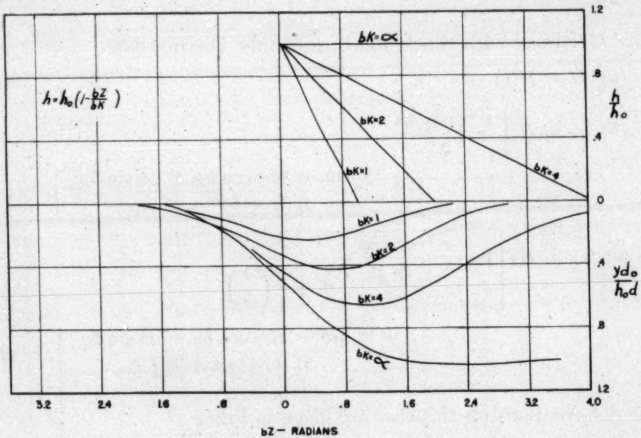

FIG. 3. Deformed figure of lithosphere for a triangular load defined by $h = h_0(1 - bz/bk)$.

VERTICAL STRESS AND GRAVITY DEFECT.

The principal term of the gravity anomaly Δg and the vertical stress S_v developed by the deformed lithosphere may be written by use of

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Eqs. (3) and (25) of reference 3*b* as

$$H - y = \frac{\Delta g}{2\pi\gamma d_0} = -\frac{S_v}{d_0 g}, \tag{17}$$

where γ is the gravitational constant. Thus, since the distribution of y and H may both be either determined or observed, it is clear that the gravity defect Δg may easily be evaluated. In Figs. 1, 2, and 3, this quantity and its distribution may be seen almost by inspection. As an illustration of the method, suppose that it is desired to obtain the distribution of gravity defect at the boundary of a continent where the basement slopes off uniformly to deep water. Assume that no sediments have been deposited and the only external load imposed on the lithosphere after it has cooled enough to develop great strength is the load due to the encroaching and subsequently formed sea. Suppose the sea is 5 km. deep, its density is 1.03 gm./cm.³, and that the distance from shore to deep water is 120 km. Since $1/b = 120$ km. over most

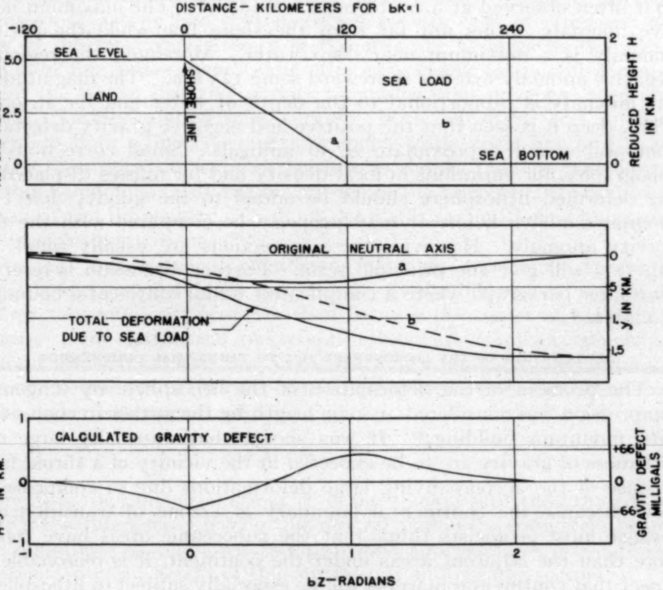

FIG. 4. Deformation of lithosphere and resulting gravity defect for a sea load applied at a continental boundary.

of the earth,[3] the load is divided into two sections, (*a*) a triangular load with $kb = 1$, and (*b*) a block load with $kb = \infty$. The deformation of the lithosphere y is the sum of the deformations of each; and these may be determined directly from Fig. 3 and plotted in Fig. 4. The difference between the reduced load H and the lithospheric deformation y is then plotted, and by Eq. (17) this difference is proportional to the gravity defect Δg. Thus, by Eq. (17) an auxiliary scale for Δg may be employed on the same plot as $H - y$. It is interesting to note that even in this very simple and idealized case the distribution of gravity is much like that often observed at a continental boundary.[1] The maximum negative anomaly occurs not far from the shore line while the positive anomaly is a maximum near deep water. Moreover, the region of negative anomaly extends shoreward some 125 km. The magnitude of the anomaly is proportional to the depth of water and for an ocean 5 km. deep it is seen that the positive and negative gravity defects are comparable and approximate ± 50 milligals. Small corrections for topography, for variations in local density and for masses displaced by the deformed lithosphere should be added to the gravity defect Δg calculated above before it may properly be compared with the true gravity anomaly. However, these corrections are usually small and Eq. (17) will give the principal term. Further discussion is reserved for a later paragraph where a complicated actual continental boundary is analyzed.

DEFORMATION OF THE LITHOSPHERE DUE TO TANGENTIAL COMPRESSION.

The problem of the deformation of the lithosphere by tangential compression was considered at some length by the author in connection with mountain building.[3a] It was shown that unusually large disturbances of gravity are to be expected in the vicinity of a thrust fault because of the accompanying large deformations due to compression. Now, because the continental boundary is a zone of transition and because most geologists think that the suboceanic areas have cooled more than the adjacent areas under the continent, it is reasonable to expect that continental margins will be especially subject to lithospheric stresses arising both from thermal contraction and from its deformation. One may reasonably expect, therefore, that continental margins should often show signs of gross fracture. At least two examples seem important: first, the Eastern coast of the United States considered in the present paper, and second, the Western South American coast. Gutenberg and Richter [4] have shown that along the Western shore of South America shallow earthquakes occur preferentially near the oceanic boundary. Earthquakes of intermediate depth occur some hundreds of kilometers inland, while the deep focus earthquakes systematically occur about 900 kilometers inland. Because the distribution follows the coast line in a surprising manner, it seems possible that these earthquake disturbances mark the transition boundary of a great thrust fault, making an angle of approximately 40° with the horizontal. If, in addition, this area is subject to gross tangential compression, then it is probable that the continental areas will be uplifted while the adjacent oceanic regions will be depressed. The uplifted areas will exhibit a mountainous structure and show positive gravity defects. The adjacent oceanic deeps, however, will have strong negative gravity anomalies of a type like that predicted by Eq. (29) of reference 3*b*. Thus, if the tangential stresses in the area are as large as the great heights of the Andes suggest, the adjacent oceanic areas will perhaps exhibit the largest negative gravity anomalies that have yet been observed. Gravity and seismic surveys, both on shore and at sea, preferably along a line taken at right angles to the coast line, will be of greatest theoretical importance because it should then be possible to determine unambiguously the magnitude of the tangential stress in this section of the lithosphere. A more detailed examination of this area awaits such observational data.

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[4] *Bulletin, Geological Society,* **49**, 249 (1937).

Another compressional phenomena of some importance at continental boundaries should be mentioned. If the lithosphere is subject to large tangential compression, then because the center of tangential pressure on the continental and oceanic sectors are usually at somewhat different levels, it is clear that an overturning couple may be produced. This couple per unit width M_1 of the lithosphere due to the overriding of the higher continental area is

$$M_1 = S_t T v, \tag{18}$$

where S_t is the tangential stress, T is the thickness of the lithosphere, and v is the difference in level of the neutral axes of the equivalent beam. The quantity v is unknown but probably approximates one-half the difference in mean height of the continental and oceanic sectors.

Since a couple is equivalent to two equal and oppositely directed forces separated by a finite distance, it may be shown by Eq. (14) of reference 3*b* that

$$y = \frac{M_1 b^2}{d_0 g} \epsilon^{-bz} \sin bz. \tag{19}$$

By employing Eq. (17) above, the accompanying gravity defect may be evaluated. This overturning moment in the lithosphere produces gravity defects that approximate observed distributions near continental boundaries, but a short calculation will show that the probable amplitude will seldom exceed 10 milligals.

DEFORMATION OF THE LITHOSPHERE AND GRAVITY DEFECTS NEAR CAPE HENRY.

The Cape Henry region of the Atlantic coast has been well studied both by gravimetric and seismic methods. Swick [5] has discussed the gravity results of the Coast and Geodetic Survey as well as the seismic results of Ewing and colleagues [6] and has remarked upon the inability of the light sediments in this region to account for the large observed negative gravity anomalies. G. P. Woollard [7] has also discussed these data and gives a curve of the observed distributions for both the sedimentary load and the gravity anomaly. Unfortunately, near and beyond the continental shelf observational data are entirely lacking and this limits the accuracy of the present comparison.

Assume that sometime in the geological past the lithosphere under the Atlantic Coast was tilted and submerged, probably as a result of the differential cooling of continental and oceanic areas. If the area was large, then it would, at first, be in substantial isostatic equilibrium. However, as the region tilts, the additional loading off shore due to the encroaching sea or to deposited sediments will deform the lithosphere, setting up in it stresses of calculable magnitude. With a knowledge of this deformation the resulting disturbances of gravity may easily be determined and compared with observation. In this investigation, the lithospheric constant b is assumed to be the same throughout the considered regions.

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Figure 5*A* shows the "reduced" equivalent load distribution of sea and sediments along a traverse of the Cape Henry area as deduced from references 6 and 7. In evaluating this load it is natural to assume that the surface of the crystalline basement represents the original surface and that all material lying above it represents a superposed load applied after the formation of the ocean basin and the development of great crustal strength. It is easily shown employing Fig. 1 that the load of the sea in this area alone is not competent to account quantitatively either for the magnitude or distribution of the observed gravity defects so that the assumption of the additional sedimentary load seems necessary. The densities of the sedimentary loads are not well known but no great error will result if one assumes that their mean density is 2.70 gms./cm.^{3}. Further, continuing earlier assumptions, the density of the underlying weak asthenosphere is taken as 3.14 gms./cm.^{3}. Assuming these values, the "reduced" load height carried by the lithosphere is derived by finding the height of columns of density $d_0 = 3.14$ gms./cm.^{3} that will represent the actual existing load. The water load itself is considerable, for example, the reduced equivalent load height H for the sea of density 1.03 gms./cm.^{3} and depth 4.5×10^5

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[5] C. H. Swick, *Bulletin Am. Assn. Petrol. Geol.*, **21**, 333 (1937).

[6] Ewing, Crary and Rutherford, *Bull. Geolog. Soc. Am.*, **48**, 753 (1937).

[7] G. P. Woollard, *Tran. Geophys. Union*, **3**, 317 (1939).

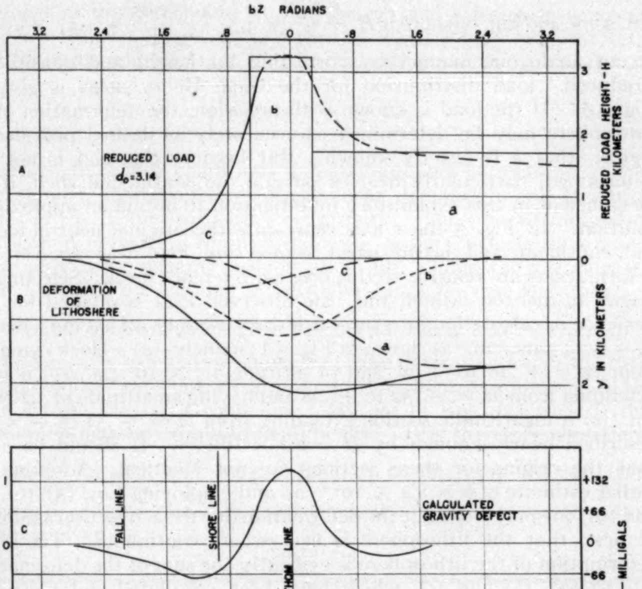

FIG. 5. The deformation of the lithosphere and resulting gravity defects in the Cape Henry Area.

cm. some 400 km. offshore is $H = \dfrac{h_0 d}{d_0} = 4.5 \cdot \dfrac{10^5 \cdot 1.03}{3.14} = 1.47 \times 10^5$ cm. In an analogous manner by correcting for height and density, the "reduced" load distribution for the Cape Henry areas is given in Fig. 5*A*. If the load is known with precision, the deformation of the lithosphere may be determined as accurately as desired provided, of course, that b is exactly known. But because the load is not well determined, particularly near or outside the continental shelf, it will be sufficient in this exploratory investigation to obtain an approximate solution. In Fig. 5 the z axis represents the original neutral axis of the continent and ocean basin before any load was applied. All deformations are relative to this original reference level. Selecting the origin at the 100 fathom line, the observed load is divided for convenience in calculation into three arbitrary sections all having a density $d_0 = 3.14$ gms./cm.^{3} as shown in Fig. 5*A*; namely, (*a*) a block extending from $bz = +.28$ to $+\infty$ and of altitude 1.7×10^5 cm., (*b*) a block extending from $bz = -.52$ to $+.28$ and having an altitude of 3.2×10^5 cm., (*c*) a logarithmic section extending from $bz = -.52$ to $-\infty$ and described nearly enough by $H = 2.2 \times 10^5 \epsilon^{-2bz}$. It should be noted that the origins for these sections are not identical. Adopting the earlier estimate of $b = 8.4 \times 10^{-8}$ cm. and employing Eqs. (5), (6), (8), and (9), one may work out the deformation due to each section assuming, at first, that the lithosphere is everywhere continuous. The entire deformation of the lithosphere is evidently the sum of the deformations due to (*a*), (*b*) and (*c*), which have been calculated and plotted in Fig. 5*B*. From the distribution of the reduced load and the total deformation of the lithosphere, $H - y$ may be evaluated and its distribution determined. Thus, by Eq. (17) the scale of Δg equivalent to the plotted values of $H - y$ in Fig. 5*C* may be determined and compared with the anomalies in Fig. 5*D* given by Woollard. Even though the anomalies of Fig. 5*D* assume isostasy and therefore are not especially suitable for comparison, yet it will be seen that the calculated gravity defects and the observed anomalies are somewhat similar both in regard to magnitude and distribution as far as the observed values are known. The calculated defect of gravity increases rapidly to positive values somewhat nearer shore than is actually observed. This probably indicates that the load of sediments near and somewhat outside the hundred fathom line has been underestimated and instead of the basement curving upward as the assumed load suggests, the trend appears to be still downward. In any case, the discrepancy between the observed and calculated values over most of the surveyed traverse is not great. One exception exists for, although the observational data are incomplete, the positive anomalies seem to be small near the continental shelf, whereas the present calculations suggest that the positive anomalies in this region are comparable to the negative values. The gravity defects considered in this paper and due to the vertical stresses in a strong lithosphere can be shown to average out when integrated over long paths taken at right angles to long linear earth features, or

$$-\int S_v dz = \int \overline{\Delta g} dz = 0. \tag{20}$$

Departures from this condition, if real, represent corrections due to topography, to disturbances of density near the station, and to uncertainties in the theoretical values for gravity. The present method of investigation provides a comparison of the gravity defects for a given region with those existing nearby and thus avoids the complicated details involving the amount and distribution of the compensation.

THE ELASTIC STRENGTH AND RUPTURE OF THE LITHOSPHERE NEAR CAPE HENRY.

The foregoing calculations have led to the determination of the total vertical deformation y of the continuous lithosphere, as a function of the distance from the 100 fathom line. By aid of Eqs. (4) to (16) this deformation may be expressed analytically. It is therefore possible to evaluate $\frac{d^2y}{dz^2}$ for each load and sum them up to determine the curvature for the entire loaded area. But since the stress at the extreme fibre S_f of a beam is given by

$$S_f = \frac{ET}{2} \frac{d^2y}{dz^2}, \tag{21}$$

one may estimate and plot the distribution of fibre stress in the lithosphere. Thus, from Fig. 5*E*, one may see that the stress at the extreme fibre is large offshore and decreases to zero about 175 km. from the 100 fathom line but increases again to a subsidiary broad maximum value at about 250 km. One notes that, at sea, the value of $\frac{d^2y}{dz^2}$ is such that the top of the lithosphere is under compression while the bottom is under tension. Here, however, the bottom of the lithosphere is subject to the compressive influence of the 50 km. column of material above it so that it can hardly fail by tension. On the other hand, at the landward end of the beam the bottom is under compression while the top is in tension. In this upper region there is no superposed compressive stress to neutralize, in part, the tensional stress and this region is likely to fail by tension if it is reasonably stressed. Obviously, failure will occur at the place where the stress in tension is a maximum. At Cape Henry this calculated region of maximum stress by Fig. 5*E* is 250 km. inland from the 100 fathom line and corresponds remarkably well with the observed position of the Atlantic Coast Fall Line. It is important to note that the position of this maximum depends upon the distribution of the load and not at all upon its size. Adopting $E = 10^{12}$ dynes/cm.^{2}, $T = 5 \times 10^6$ cm., it is found from Eq. (21) that the stress at this maximum would be 8.5×10^8 dynes/cm.^{2} if the lithosphere were everywhere homogeneous and unbroken. Clear observational evidence of a Fall Line that follows up the Atlantic Coast shows that the lithosphere broke in tension long ago. Therefore, the load of deposited sediments then must have been lighter than it is now. This means necessarily that the effective strength of the lithosphere in tension at that time was less than 8.5×10^8 dynes/cm.^{2}.

The failure of the lithosphere in tension may have been partial or complete. The present existence of the Fall Line shows that the fracture resulted in relative vertical movement and the whole coastal plain area was lowered while the inland area was upraised. Perhaps the fracture only released the excess stress and the underlying regions healed themselves. If this is true it is quite impossible to say when equilibrium was reached. However, if the break was complete, then it is possible to calculate the deformation after the break. One notices first, that the break appeared at the place where the bending moment was a maximum, and therefore the shear was zero. Thus, just before fracture, only the bending moment at the break is responsible for the stability. Therefore, after fracture, contrary bending moments of the same magnitude may be applied to each end of the broken sections to determine the resulting approximate deformation due to the release of the stresses. The deformation due to these couples may be determined by Eq. (16) of reference 3*b*. It is found from the data of Fig. 5*E* and Eq. (7) of reference 3*b* that before fracture the couple M_0 at the maximum was 3.6×10^{21} dynes-cm., from which it is estimated that the maximum height of the resulting fault scarp is twice the deformation of each broken end or a total of 0.32 km. Such a value is a maximum because it is perhaps probable that the break was simply an act of stress relief and a perfectly clean break did not result. Because the geological data necessary to determine the amount and distribution of sediments deposited after the break are not now available, corrections to the calculated gravity defects for this phase of development are impossible. It is evident from Fig. 5, however, that the calculated actual distribution of gravity defect is not unlike that now observed except, of course, subsequent sedimentation has erased the marked discontinuity initially existing at the Fall Line.

If the Cape Henry area is typical of the Atlantic Coast, then it should be apparent from the above investigation that a strip of negative gravity anomaly should parallel the Eastern coast and as deep water is approached, there should be a notable algebraic increase in the value of the anomaly. Only a small part of this phenomena appears to be attributable to the so-called "coast effect" of isostasy and to abnormal departures in density in nearby regions. The principal part of the

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phenomena is thought to be due to a strong deformed and stressed lithosphere satisfying the condition that $\int \Delta g dz = 0$ and having such a rigidity that a localized load will be supported appreciably out to distances of the order of 230 km. As a general rule, areas of negative anomaly will lie well to the landward side of the region of maximum specific loading, while positive disturbances will be generally encountered nearby.

In one sense the Cape Henry area is unsatisfactory for study because the break leads to uncertain values for the present superposed stresses in the lithosphere. But it should be clear from Fig. 4 and Fig. 5 that the gravity anomaly distribution at a coast line not actually broken is somewhat similar to that observed in the Cape Henry area. Moreover, the occurrence of a Fall Line near the line of maximum stress appears to the author to add considerable interest to the calculations for this area. Although the above investigation has been applied to an area having a wide coastal plain, it is clear that the methods of investigation are applicable to any continental boundary where the applied load can be estimated.

DISCUSSION.

In concluding this series of papers on the properties of the lithosphere and isobaric equilibrium, it may be remarked that many refinements are possible. Probably the physical constants of the lithosphere vary somewhat at different depths and positions and therefore, the present idealized treatment is not everywhere as accurate as one might wish. Extended solutions for the three-dimensional case, although awkward, appear possible and may be necessary before certain detailed geological features can be quantitatively discussed. However, these refinements will not influence the physical interpretation of the considered long linear geological structures. Much work remains to be done in the evaluation of the corrections that must be added to the principal term of the gravity anomaly we have discussed, to make it strictly comparable to the true gravity anomaly. Such corrections will involve the same type of analysis as employed in isostatic reductions but will be more complicated because the compensations of many earth features will not lie immediately below them. Perhaps this difference will be negligible for features outside a radius of 1,000 km. but the matter of corrections to the principal term needs further study.

All the investigations made by the writer on the properties of the lithosphere emphasize its fundamental rigidity and strength. It apparently does not flow or steadily yield under appreciable applied loads even when these are applied for thousands of years. Tangential stresses greatly exceeding those geologically encountered seem necessary grossly to buckle or fold it as a whole, and most gross deformations result from some nearby shear or tensional failure.[3a] Since the characteristic dimension of the lithosphere is $1/b$ or 120 ± 25 km., it follows that its significant deformations will extend over somewhat comparable linear dimensions. Finally, it should be observed that the existence of great regions of gravity disturbance over the earth guarantees that the earth's crust has great strength and that the isostatic requirement of a mechanically weak crust is a fiction. It is thought that the papers show rather clearly that a strong lithosphere plays a crucial part in accounting for observed anomalies of gravity, that these disturbances of gravity may be calculated approximately from simple mechanical principles and that the principle of isobaric equilibrium is fundamentally necessary to describe the equilibrium of the earth's crust near mountains, ocean deeps or other superposed earth features.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

TEXTILE RESEARCH INSTITUTE.

The efforts to establish a central organization for textile research in the United States, which have gradually gathered support over a period of years, and in which the Bureau has played an important part, were crystallized at the annual meeting of the Textile Research Institute in New York on November 18. The plan of the Institute outlined at that meeting provides for: (1) Coverage of all branches of the textile industry, and all fibers; (2) location of the Institutes' laboratories near New York; (3) development of a program covering fundamental research, applied research, a graduate school, and information service, etc.; (4) raising of a research fund of $300,000 a year for five years, or $1,500,000 plus a capital fund of $500,000.

Dr. Milton Harris, director of research for the Textile Foundation at the Bureau, is to serve also as director of research for the Institute. William D. Appel, chief of the Bureau's textile section, is chairman of the Applied Research Committee of the Institute, and a member of the Board of Directors.

OIL AND WAX TREATMENTS OF SOLE LEATHER.

The possibility of using oil and wax treatments commercially to improve the wear of sole leather is receiving increased attention as a result of service tests conducted by the Bureau's leather section, as part of a cooperative project of the Interdepartmental Committee on Leather. These tests, which are described in Letter Circular LC 739, showed that resistance to wear was increased about 15 per cent. by treating the soles with a mixture of mineral oil and solvent, and as much as 30 to 40 per cent. by impregnation with hot wax. It has been demonstrated that these treatments can be used satisfactorily on soles that are to be stitched or nailed to the shoes, either by the manufacturer or the repairer. (Stitched or nailed soles are used on about 250,000,000 pairs of new shoes each year in this country.) The practicability of using these treatments on soles that are to be cemented to the uppers has been uncertain, because the bond between sole and upper has been rendered insecure when the sole is treated. (Cemented soles are used on about 150,000,000 pairs of shoes annually.) Preliminary tests by other members of the Interdepartmental Committee indicate that the treatments can be used satisfactorily with this type of construction by roughening and applying adhesive to the portion of the sole that is to be cemented, allowing it to dry, and then applying the treatment.

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* Communicated by the Director.

Copies of LC 739 are obtainable without charge from the National Bureau of Standards, Washington, D. C.

NATURAL RUBBER AND SYNTHETIC RUBBER.

In an address on November 5, 1943, at the Instituto Agronomico do Norte, in Belem, Para, Brazil, Dr. Norman Bekkedahl discussed natural rubber and synthetic rubber from the point of view of the research worker familiar with the advantages and disadvantages of both materials. His conclusion is that there will always be a field for the natural product, particularly if its quality is improved through research. He feels certain that this can be accomplished—in fact, this is the primary object of the work of the rubber laboratory which he is directing at Belem while on loan by the Bureau to the Brazilian Government.

Thus, in the case of automobile tires, which before the war absorbed over 50 per cent. of the world's output of rubber, natural rubber has one advantage—under most circumstances it does not convert into heat so large a proportion of the mechanical energy produced by flexing the tire as does synthetic rubber. Perhaps a tire made from a combination of natural and synthetic rubber will ultimately be adopted.

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The paper discusses the development of the synthetic rubber industry and points out that it was not till the attempts to produce artificial rubber which was of the same chemical composition as natural rubber were given up, that commercial success was achieved. Some of the synthetic rubbers now in production are not hydrocarbons at all, and because they are not, they possess certain valuable properties. Thus, they are resistant to petroleum and hence, are widely used in the manufacture of gasoline hose, gaskets, and other products. Moreover, the so-called Neoprene rubbers contain such a high percentage of chlorine that they will not burn, giving them a great advantage for use in places where fire hazards must be avoided.

All the synthetic rubbers are better able to absorb vibrational energy than natural rubber, so that they are ideal as a material for blocks or pads to place under or between parts of machines. On the other hand, this mechanical energy is converted into heat and this, as already mentioned, is a disadvantage which must be overcome in the building of tires.

Almost certainly the demand for rubber will increase after the war. New uses will develop and some of these can best be met by natural rubber. Every effort should be made to improve its quality. There is a possibility that varieties of trees exist that can produce more and better rubber than the customary Hevea brasiliensis. New hybrids can be grown that will show increased resistance to disease, and the rubber from many varieties of plants, now but little known, should be investigated. There is no reason to be pessimistic over the future of natural rubber.

Copies of Dr. Bekkedahl's paper are obtainable from the Instituto Agronomico do Norte, Belem, Para, Brazil. Notes on the Brazilian rubber laboratory will be found in Technical News Bulletins Nos. 308 and 316 (December, 1942 and August, 1943).

HYDROCARBONS IN THE GASOLINE FRACTION OF PETROLEUM.

Research Paper RP 1571 in the January number of the *Journal of Research*, by A. F. Forziati, C. B. Willingham, B. J. Mair, and F. D. Rossini, was originally presented on November 10, 1943, before the division of refining at the annual meeting of the American Petroleum Institute in Chicago. This is the second report of an investigation on the analysis of the gasoline fraction of representative crude petroleums by the API Research Project 6 at the Bureau. The samples for analysis were selected so as to cover the largest possible range in composition; they included one high in aromatics, one high in isoparaffins, one high in normal paraffins, and one high in naphthenes (cycloparaffins), and came from the following fields: Ponca, Okla.; East Texas; Bradford, Pa.; Greendale-Kawkawlin, Mich.; Winkler, Texas; Midway, Calif.; Conroe, Texas. The fractionating processes of adsorption and distillation were used in analysis.

Data are given on the amounts of the individual hydrocarbons (paraffins and naphthenes, 40° to 102° C., and aromatics to 160° C.) in the gasoline fraction of the seven naphthas. A number of conclusions have been drawn from the data, as follows:

1. The gasoline fraction of different crudes may be characterized by specifying the relative amounts of the following five classes of hydrocarbons: Normal paraffins, isoparaffins, alkyl cyclopentanes, alkyl cyclohexanes, and aromatics.

2. These gasoline fractions are composed of the same hydrocarbons; the essential difference between them is in the relative amounts of the foregoing five classes of hydrocarbons which they contain.

3. Within each of these five classes, the individual hydrocarbons occur in proportions which are of the same order of magnitude for different naphthas.

4. It appears possible to predict the order of magnitude of the amounts of the individual hydrocarbons, paraffins and naphthenes, 40° to 102° C., and aromatics to 160° C., present in an appropriate fraction of a given naphtha when there are known the relative amounts of the foregoing five classes of hydrocarbons, or, alternatively for each class, the amount of one of the main components of that class.

HOW TO SAVE DOMESTIC FUEL OIL.

The value of a fireplace in relieving the load on the main heating plant of the usual dwelling house is brought out in Letter Circular LC738 "Notes on domestic fuel oil conservation" which has been prepared to answer the numerous inquiries received at the Bureau on this subject. Although sometimes inefficient, fireplaces do supply a certain amount of heat, which in the case of a good design and location, may appreciably reduce the oil consumption and even the total heating cost. A good stove may be more efficient since the loss of heat up the chimney is generally less than in the case of a fireplace.

If a fireplace is not in use, the damper, should be closed, or if there is no damper, the flue opening should be covered. A very small fire in a fireplace may actually cool a room because the fire will increase the draft up the chimney and hence the escape of warm air from the room and will throw out but little heat. In other words, a certain minimum fire must be burned to heat a room, and this can be determined only by experiment.

A tight house cuts down oil consumption, but if a room is too tightly closed, the fireplace may smoke. Weather stripping, window sealing materials, storm windows and doors are all valuable in keeping heat inside a house, and hence in reducing the amount of oil burned, but a certain amount of ventilation is essential and the heat loss that goes with it is unavoidable. Turning down the thermostat at night or when the house is unoccupied saves fuel as explained in a previous Letter Circular, LC711. Often one or more occupied rooms can be kept at a comfortable temperature by using a fireplace or stove in combination with the main heating plant while the rest of the house is maintained at a uniform lower temperature by the heating plant alone.

Copies of LC738 are obtainable without charge from the National Bureau of Standards, Washington, D. C.

REFRACTIVITY OF OPTICAL GLASS.

The manufacture of optical glass in large quantities for precision uses necessitates many measurements of refractive index that cannot be made with needed accuracy on refractometers. The time required for the precise computation of indices after measurements of minimum deviation on prisms of various angles near 60° is materially shortened and the chances of error are reduced by using special tables and a slide rule instead of logarithms or a computing machine. Helen L. Gurewitz and Leroy W. Tilton have prepared one such table by merely doubling the values read from a table of natural sines at intervals of 15 seconds of arc. This is really a table of refractive indices for a prism of exactly 60° listed as a function of (double) deviation. A second table of auxiliary coefficients has been prepared for changing the actually observed (double) deviation for any prism of 60° ± 30′ to the corresponding (double) deviation for a prism of exactly 60°. This permits the first table to be used for all prisms in the range 60° ± 30′. Copies of these tables and a discussion of methods for determining refractive index and dispersion of optical glass so as to control its quality will be published as RP1572 in the January number of the *Journal of Research.*

DICALCIUM SILICATE SOLID SOLUTIONS.

The manner of combination of sodium oxide in portland cement clinker is the subject of a series of investigations at the Bureau. In certain experimental preparations made in the course of this work, crystalline phases have been observed that, although known to be composed almost entirely of dicalcium silicate ($2CaO.SiO_2$), yet exhibit optical properties differing from those of the $2CaO.SiO_2$ of commercial clinker. These phases result when samples of $2CaO.SiO_2$ to which small amounts of Na_2O and Al_2O_3 or of Na_2O and Fe_2O_3 have been added, are quenched from temperatures of 1450° to 1500° C.

The nature of these crystalline phases has been studied by optical, thermal, and x-ray diffraction methods, and is reported in a paper by Kenneth T. Greene in the *Journal of Research* for January (RP1570). The data indicate that, at high temperatures, Na_2O plus Al_2O_3, or Na_2O plus Fe_2O_3, enter into solid solution in the $2CaO.SiO_2$, producing phases which are metastable at room temperature but which may be preserved by quenching. These metastable solid solutions have hexagonal crystal structures, and evidence was obtained that this hexagonal lattice is fundamental for the form of $2CaO.SiO_2$. In one of these preparations the α–β inversion temperature of $2CaO.SiO_2$ is lowered from 1420° C. to 1175 ± 10° C., and in another to 1180° ± 10° C.

When the hexagonal phases invert to the β form, the material in solid solution is precipitated as minute inclusions, causing the grains of $2CaO.SiO_2$ to resemble those in some commercial clinkers. Many of the grains also exhibit a complex twinning structure similar to that often observed on the $2CaO.SiO_2$ of commercial clinker. The data indicate that this twinning is produced by the inversion from the α to the β phase.

Record Voice on Hair-Like Wire.—Sixty-six minutes of continuous speech can be recorded on 11,500 feet of hair-like steel wire on a spool no larger than the ordinary doughnut, in a new type of wire sound recorder being built by General Electric Company.

Operating under a license of the Armour Research Foundation, engineers in General Electric's laboratory are now engaged in redesigning the apparatus so that it can be manufactured in mass production to meet the demands of both Army and Navy.

The recorder, itself, is contained in a small box, weighing about 9 pounds. It has many wartime uses but perhaps none more important than in observation planes. Instead of the customary pad and pencil now used by pilots in making notes of what they see on scouting trips, they can dictate into a small microphone just as the busy office executive now uses a dictaphone. Instead of the observer's words being recorded on a wax cylinder they are recorded magnetically on a wire which is but four one-thousandths of an inch in diameter.

Unlike the wax cylinder which is breakable, there is no apparent wearout to the wire. In fact, 100,000 reproductions have failed to alter its quality in any respect.

When there is no longer any use for the recordings, the speech can be readily "wiped off" magnetically, and the wire is as good as new for future recordings.

Magnetic steel wire recording is not a new idea. As early as 1898 Valdamar Poulson, a Danish scientist, introduced the method and used it to record high speed arc radio signals. However, suitable amplifiers were not available at that time and the quality was poor. With the new method developed by Marvin Camras, assistant physicist of the Armour Institute, many changes have been made and the quality improved so as to compare favorably with the ordinary phonograph records.

A recent report from England stated that the sound recorder is now being used in the war zones and that a "fight talk of a Flying Fortress crew, attacking Nazi airfields in France, was recorded on a small spool of wire."

This was brought back to England, and according to Major H. L. Nussbaum, "All the conversation of the crew inside the Fortress as well as the sounds of battle was brought back as an oral record of the 66-minute flight."

R. H. O.

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THE FRANKLIN INSTITUTE.

ANNUAL MEETING, JANUARY 19, 1944.

Mr. Charles S. Redding, President, called the meeting to order at 8:20 P.M. on Wednesday, January 19, 1944, after the audience had stood at attention for the playing of the National Anthem.

He announced that this was the Annual Meeting of The Franklin Institute.

The statement was made that the minutes of the previous meeting had been presented in full in the January number of the JOURNAL OF THE FRANKLIN INSTITUTE. Objections were called for but none being offered the minutes were declared approved as presented.

The President then called on the Secretary, Dr. Henry B. Allen. Dr. Allen made the following report of additions to membership:

Active	90
Associate	14
Student	28
Total	132

In accordance with the By-Laws, the Tellers had been duly appointed to tally the elections. The Secretary made the following report of the Tellers findings:

President (to serve one year)	Charles S. Redding
Vice-Presidents (to serve one year)	Walton Forstall
	W. Chattin Wetherill
	S. S. Fels
	Richard W. Lloyd
	Richard T. Nalle
Treasurer (to serve one year)	Morton M. Price
Managers (to serve three years)	G. H. Clamer
	Clarence L. Jordan
	Lionel F. Levy
	Charles Penrose
	James H. Robins
	Philip C. Staples
	Philip H. Ward, Jr.
(to serve one year)	Clarence Tolan, Jr.
	William M. Vermilye

Respectfully submitted,

GEORGE S. CRAMPTON,
J. LOGAN FITTS,
JAMES D. LEE, JR.,
Tellers.

The Secretary then declared the gentlemen named duly elected to the various offices for the times indicated.

Appreciation to the Tellers for their very helpful service was then expressed by the President.

Mr. Redding also expressed appreciation on behalf of himself, fellow officers and the Board of Managers for the continuing confidence placed in them by members of the Institute as indicated by this return to office.

The President then stated that the Board of Managers at a meeting in the afternoon had approved the report of the President and had instructed him to present it at this annual meeting. He stated that in deference to the speaker he would give only a brief summary, but that the report would be printed in full in the January number of the JOURNAL OF THE FRANKLIN INSTITUTE.

(The report follows these minutes.)

The speaker of the evening, Mr. Games Slayter, Vice-President and Director of Research, Owen-Corning Fiberglas Corporation, was then introduced. He spoke on "Some War-time Developments in the Field of Minerals and Their Peace-time Implications." His paper called attention to war spotlights savings in weight, bulk and costs through use of materials for purposes for which they are best fitted, and in their most economical fabricated forms. His talk was well received by an interested audience who spent considerable time afterwards in asking questions regarding the speaker's subject.

The meeting was finally terminated by a rising vote of thanks to the speaker.

HENRY BUTLER ALLEN,
Secretary.

January 19, 1944.

Report of the President to the Board of Managers of The Franklin Institute of Pennsylvania, Covering the Operations of the Institute for the Year 1943.

This report is a brief summary of the financial operation and of the activities of The Franklin Institute for the year 1943.

The property of the Institute is entered on its books at $5,776,000. Of this amount, real property (the building and equipment, not including those exhibits which have been donated) amounts to $4,115,000, and personal property (securities and cash) amounts to $1,661,000. The value of real property here reported is $7,000 higher than that reported for the preceding year, due to the purchases of some equipment items during the year, and to increases in supplies inventories. The value of personal property here reported is $93,500 higher than that reported for the preceding year. Contributing to this increase were the receipt during the year of $78,000 from the settlement of the W. C. L. Eglin Fund and that portion of the operational gain for the year, to be referred to later, which has actually been realized in cash settlements. At the end of 1943, we had a cash balance of $69,900 as compared with $7,100 at the end of 1942.

Not entered on its books, except statistically, is certain other property consisting of exhibits, etc., which came to the Institute as gifts.

The following figures, covering income and expense, are subject to minor adjustments after the books are closed.

Income	1943
From dues	$ 46,500
" admissions	37,200
" investments	66,500
" other sources *	485,000
" Friends of Franklin	23,000
	$658,200

* $409,000 of this item represents work done for and space provided to Government departments in connection with the war work.

Expenses	1943
General	$184,300
Museum Operation	82,900
Publications	15,200
Meetings, etc.	1,950
National Franklin Committee	18,000
Other *	292,700
	$595,050
Gain for the year	$ 63,150

* All but about $5,000 of this item covers direct outlay in connection with Government work.

For the year 1942, we reported a deficit of $31,900. This year's gain of $63,150 was due entirely to the large amount of Government work done at the Institute during the year. We are compensated for this work by being paid for the direct payroll and material expenses, to which is added an overhead percentage on the direct payroll. Practically all of our scientific staff is working upon Government projects to the exclusion of our regular Institute activities. While this transfers a large part of our payroll to a reimbursable account, it follows that we are sacrificing much of our Institute and Museum activities in order to help win the war. The favorable financial situation reported this year will not continue after our war work ceases. We will then again be faced with our old problem of finding ways and means of balancing our budget.

At the end of 1943 the Institute's investments in securities were:

Largely available as to income only	$ 651,600
Available unrestrictedly	939,600
	$1,591,200

The membership, all classes, totaled 5,764. This shows a gain of 1,087 as compared with 1942.

Admissions to the Museum and Planetarium, with comparable figures for 1942, were as follows:

	Museum		*Planetarium*		*Total*	
	1943	1942	1943	1942	1943	1942
Paid	106,383	108,295	53,647	57,964	160,030	166,259
Free	33,037	27,267	22,998	19,228	56,035	46,495
	139,420	135,562	76,645	77,192	216,065	212,754

During the year 14 Institute lectures were held. Altogether there were 336 meetings of various kinds at the Institute.

Your Officers and Managers are again gratified and heartened by the generous financial assistance of Friends of Franklin. It will have been noted that during the year that group contributed $23,000. We earnestly solicit the continued support of these staunch friends. During these days when our war activities have turned continued deficits into a surplus, their contributions help replace amounts which in prior years have been taken from capital funds, and when our war work ceases we will need their support even more than in the past.

Despite the transfer of the activities of a large part of our technical staff to war work, the Museum and Planetarium have continued to function, although during the year additional Museum space was turned over to war activities. We have felt, and it is believed rightly, that we should try to keep the operation of the Museum and Planetarium as nearly normal as conditions would permit. Much credit is due to those members of our staff who have carried on this work so creditably under existing circumstances. Some thought is even now being given to preparation for the post-war era when there will be many new ideas, now hidden by war secrecy, which should be demonstrated to the public.

Our exhibits, exhibitions, and demonstrations have all had to be planned to take as little strategic materials and manpower as possible. The result has not been what we would have liked, but it has been better than nothing. So far as possible, emphasis has been placed upon items of current interest, wherever there has been no conflict with Governmental restrictions.

The Industrial Coöperation Program, instituted in the fall of 1939, has continued to function. As a result of this Program $19,500 was contributed during 1943. This amount came largely from those industries having exhibits in the Museum, but the contributions were entirely upon a voluntary basis. Since the beginning of this Program 95 companies have accepted our request for industrial coöperation. Under this Program the following new exhibits were opened during the year:

Steel Castings Exhibit. Placed here with the coöperation of 14 companies who are members of the Steel Founders' Society of America, and the Ajax Metal Company.
Overboard Life Suit. Presented by the Goodall Rubber Company.
How Steel Is Made. Presented by the Bethlehem Steel Company.
Welding. Presented by the E. G. Budd Manufacturing Company.

The latter two exhibits are from the "Ordnance for Victory" Show presented in Philadelphia during the summer of 1943. Additional interesting exhibits under this Program are in prospect.

During the year, in coöperation with the Curtis Publishing Company and the War Manpower Commission, there was held an interesting and valuable exhibit entitled "Women in War Work."

A program was inaugurated in 1943 whereby industrial organizations present in our Photographic Gallery the photographic story of their work. It is planned to continue this activity under a definitely established program.

As of December 31, 1942, the Institute employed 159 persons. By December 31, 1943, this number had increased to 228. The increase is entirely in connection with the war work being carried on.

At the Tenth Anniversary of the opening of the Museum and Planetarium held in November we were pleased to give credit to 41 employees who had been with us for ten years or more.

During the year Dr. Schall, Director of Museum Education, left us to become an Assistant Field Director of the Red Cross. His work is now being carried on by Mr. Spitz. A new department of Museum Research has been set up under Major Coulson to provide more information and more accurate information about our exhibits, and to analyze and improve upon our methods of presenting exhibits to the public. The work of our Public Relations Department is now being carried on by an outside organization, Campbell-Wirtz Associates.

Our very important library has continued to prove its value in connection with war work being carried on in Philadelphia and its surrounding territory. During the year it was visited 6,866 times by members and 1,095 times by non-members. 6,600 photostats of library material were furnished during the year. 5,366 telephone calls for technical information were received. 490 new books were purchased and 401 books were received as gifts. In addition, 1,714 pamphlets were received. The total contents of the library as of December 31, 1943, were as follows:

126,317 volumes
43,759 pamphlets
3,449 maps.

The Membership Committee continued to function in an admirable manner and again much credit is due to that Committee and the members of the Staff engaged in membership activities for their fine work done during the year.

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The Committee on Science and the Arts has continued its painstaking activities. During the year it held nine regular meetings, one special meeting, and forty-three sub-committee meetings. As a result of its activities and with the approval of the Board of Managers, eleven medals and one Certificate of Merit were awarded on Medal Day, April 21, 1943. It is worthy of note that due to war conditions and transportation difficulties the usual Medal Day procedure was modified this year, combining the medal presentation ceremony, usually held in the afternoon, with the dinner meeting. This departure from long-established custom seemed to be universally acceptable. At that meeting a portrait of our immediate past president, Mr. Philip C. Staples, was presented to the Institute by the Board of Managers.

The usual twelve issues of the JOURNAL were published in 1943. Due to war conditions the number of articles submitted for publication has been considerably less than usual. During the year the soliciting of additional advertising for the JOURNAL was placed in the hands of the Membership Department, resulting in increased advertising income and the likelihood of a further significant increase.

Again, the Hostess Committee has continued its usual good work in looking after the social functions held at the Institute. We are particularly grateful to that Committee for its gracious and very acceptable assistance in connection with the opening of the exhibit "Women in War Work" and the ceremonies attending Medal Day and the Tenth Anniversory of the opening of the Museum and Planetarium. At the Annual Meeting of the Committee held in October Mrs. John White Geary was reëlected Chairman and Mrs. Livingston E. Jones, Vice-Chairman. In addition to its activities in connection with our social functions, the Committee takes a real interest in our housekeeping and in the recreation rooms for the staff, besides making a substantial cash contribution to operational funds of the Institute.

Again, this year, the two Research Foundations, Bartol and Biochemical, have devoted practically all of their energies to work pertinent to various Government agencies in connection with the Nation's war activities. Their Directors made Annual Reports at Stated Meetings of the Institute, but due to the confidental nature of much of the work being carried on during the year, were not in a position to report fully upon the accomplishments of the Foundations. Financial statements of the two Foundations are not included in this report for the reason that each has its own funds disassociated from those of the Institute and not contributed to by the latter.

During the past year the National Franklin Committee has been exceedingly active in its efforts to make Benjamin Franklin better known and emulated and in bringing The Franklin Institute more prominently before the national public.

Detailed monthly reports are received from the New York office covering the activities of this committee. They are much too lengthy to quote here but are on file in the Secretary's office for anyone who would care to inspect them.

To mention a few highlights: during the past year The Franklin Institute has sent out members of its own staff to make personal contact with persons especially interested in Benjamin Franklin as indicated by their replies to the National Franklin Committee. It was found that these personal visits stimulated the interest and caused these people in turn to contact others whom they knew would be interested in Franklin. This approach is being continued during the coming year.

One direct result of the activities of the Committee may be seen around Franklin's birthday. In preparation for this, the Committee early last fall sent out 2,500 letters to house organs throughout the country asking the editors if they would care to have material on Franklin for use as quotations or as editorials and also especially requesting them to use it in January. The replies were overwhelming and some of the results are displayed on a bulletin board at the Institute.

The magazines have used simple quotations, have used in their entirety editorials written by our staff, or have sent representatives to the Institute to write up their own material, but in nearly every case in addition to this information, these publications have used a photograph of our statue of Franklin, if not as an outside cover for January, then as a prominent cut inside the magazine.

It is the belief of the Committee that in this way the statue will become nationally known by sight as the National Memorial.

To bring the work of the Institute and the National Committee in closer harmony during the past year, it was thought advisable to appoint a special committee of the Board of Managers consulting with our New York office. The results of this closer contact have been very pleasing.

During the year the Board of Managers elected the following gentlemen to membership on the Board to fill vacancies:

Mr. Clarence Tolan, Jr., President of Dodge Steel Company,

Mr. William M. Vermilye, Vice-President of the National City Bank of New York, and Chairman of our National Franklin Committee.

It was with regret that the Board accepted during the year the resignation of Mr. A. Atwater Kent as a member of the Board.

On August 2, 1943, the Board of the Institute suffered a severe loss in the death of Mr. Conrad N. Lauer who had been a member of the Board of Managers since 1936 and a member of the Institute since 1911. He had always been an interested and active member and his loss has been severely felt.

Two new Medal Awards were established during the year: first, the Clamer Medal which was given to the Institute through the will of Francis J. Clamer. It is a silver medal awarded not less than once in every five years for meritorious achievement in the field of Metallurgy and it will be given for the first time this next Medal Day. The second medal is the Newcomen Medal, founded by The Newcomen Society. It is a gold medal awarded, not oftener than once in three years, for outstanding achievement in the field of Steam. That was awarded for the first time on Monday, January 17, 1944, to Rear Admiral H. G. Bowen, of the United States Navy, for work on the application of high pressure steam to naval vessels.

Previous reference has been made to the Tenth Anniversary of the opening of the Museum and Planetarium. This Anniversary was held on November 9, 1943, and was combined with the awarding of the Vermilye Medal to Mr. Walter S. Gifford, President of the American Telephone and Telegraph Company, in recognition of outstanding contribution in the field of Industrial Management. Also, at these ceremonies, honorary memberships were bestowed upon Colonel Philip Fox, U. S. A., Mr. Samuel S. Fels, and Mrs. Mary Curtis Zimbalist.

It will be of interest to the membership to know that the Board of Managers is considering as a post-war project the establishment of some sort of an Engineering Foundation at the Institute to make available to industry the research facilities of the Institute which have been developed in connection with the war work now being carried on. It is felt that the establishment of such a function is quite in line with the purposes for which the Institute was originally founded.

During the year we were successful in securing a State appropriation to aid us in carrying on our work. This enables us to face the after-war future with more assurance.

Two portraits were received which were very gratefully accepted—one of Professor Elihu Thomson, presented by Mrs. Elihu Thomson; and the other, a portrait of Franklin, on an indefinite loan to us from the Philadelphia National Bank.

At the end of this my second full year as President of the Institute, I again express to the Officers and Board of Managers my deep appreciation for the friendly and helpful assistance in endeavoring to perpetuate the ideals and objectives of The Franklin Institute. To the men and women of the staff, my sincere thanks for their earnest and effective services rendered during 1943. In spite of continued handicaps the organization has carried on with high spirit which is deeply appreciated.

CHARLES S. REDDING,
President.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, January 12, 1944.)

HALL OF THE COMMITTEE,
PHILADELPHIA, JANUARY 12, 1944.

DR. JOSEPH S. HEPBURN *in the Chair.*

The following reports were presented for final action:

No. 3132: Brown Medal.

This report recommended the award of the Frank P. Brown Medal to HARVEY CLAYTON RENTSCHLER, of Bloomfield, New Jersey, "In consideration of his application of a source of bactericidal ultraviolet radiation in air conditioning systems in a scientific and practical manner."

No. 3133 } The Standing Sub-Committee on the Franklin Medal recommended that a
No. 3134 } Franklin Medal be awarded in 1944 to:

WILLIAM DAVID COOLIDGE, of Schenectady, New York, "In recognition of his scientific discoveries, which have profoundly affected the welfare of humanity, especially in the field of the manufacture of ductile tungsten and in the field of improved apparatus for the production and control of x-rays"; and one to

PETER KAPITZA, of Moscow, U.S.S.R., "In recognition of his remarkable contributions to experimental physics and also to theoretical physics, especially in the fields of magnetism and low temperatures."

JOHN FRAZER,
Secretary to Committee.

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat prints of any material in the collections can be supplied on request. The average cost for a print 9 × 14 inches is thirty-five cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays from two until ten o'clock P.M.

RECENT ADDITIONS.

AERONAUTICS.

DE LONGE, MERRILL E. Modern Airfield Planning and Concealment. 1943.
SPREADBURY, F. G. Aircraft Electrical Engineering. 1943.

ASTRONOMY.

BARTON, SAMUEL G., AND WM. H. BARTON, JR. A Guide to the Constellations. 1943.

BIOCHEMISTRY.

DIXON, MALCOLM. Manometric Methods. Second Edition. 1943.
SHERMAN, HENRY C. The Science of Nutrition. 1943.

BIOGRAPHY.

RAYLEIGH, LORD. The Life of Sir J. J. Thomson. 1943.

CHEMISTRY AND CHEMICAL TECHNOLOGY.

Brode, Wallace R. Chemical Spectroscopy. Second Edition. 1943.

De Golyer, E., Editor. Elements of the Petroleum Industry. First Edition. 1940.

Himus, Godfrey W. Fuel Testing. 1942.

Hougen, Olaf A., and Kenneth M. Watson. Chemical Process Principles. Part One. 1943.

Jamieson, George S. Vegetable Fats and Oils. Second Edition. 1943.

Morrell, R. S., Editor. Synthetic Resins and Allied Plastics. Second Edition. 1943.

Powers, Paul O. Synthetic Resins and Rubbers. 1943.

Read, William Thornton. Industrial Chemistry. Third Edition. 1943.

Richter, George Holmes. Textbook of Organic Chemistry. Second Edition. 1943.

Schmidt, Julius. A Text-Book of Organic Chemistry. Fourth Edition. 1943.

Society of Chemical Industry. Reports of the Progress of Applied Chemistry. Vol. XXVII—1942.

Weingart, G. W. Pyrotechnics. 1943.

ECONOMICS.

Reid, Margaret G. Food for People. 1943.

ELECTRICITY AND ELECTRIC ENGINEERING.

Albert, Arthur Lemuel. Fundamentals of Telephony. First Edition. 1943.

Federal Telephone and Radio Corporation. Reference Data for Radio Engineers. 1943.

Parr, G. The Cathode Ray Tube. Second Edition. 1943.

Pender, Harold, and S. Reid Warren, Jr. Electric Circuits and Fields. First Edition. 1943.

Poole, Joseph. The Telephone Handbook. 1942.

Wilson, W. The Cathode Ray Oscillograph in Industry. 1943.

Zepler, E. E. The Technique of Radio Design. 1943.

ENGINEERING.

Hool, George A., and W. S. Kinne, Editors-in-Chief. Movable and Long-Span Steel Bridges. Second Edition. 1943.

INDUSTRIAL MANAGEMENT.

Schutt, William H. Time Study Engineering. First Edition. 1943.

MATHEMATICS.

Hurewicz, Witold, and Henry Wallman. Dimension Theory. 1941.

Kells, Lyman M. Calculus. 1943.

Kern, Willis F., and James R. Bland. Geometry with Military and Naval Applications. 1943.

Knopp, Konrad. Theory and Application of Infinite Series. 1928.

Pontrjagin, L. Topological Groups. 1939.

Tippett, L. H. C. The Methods of Statistics. Third Revised Edition. 1941.

Weyl, Hermann. The Classical Groups, Their Invariants and Representations. 1939.

MINING ENGINEERING.

American Institute of Mining and Metallurgical Engineers. Transactions. Metal Mining and Milling. 1943.

NAVAL ARCHITECTURE.

Johnson, Gene. Ship Model Building. 1944.

Lane, Carl D. American Paddle Steamboats. 1943.

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PHOTOGRAPHY.

COX, ARTHUR. Optics. Second Edition. 1943.

PHYSICS.

EMSWILER, J. E. Thermodynamics. Fifth Edition. 1943.
PRINGSHEIM, PETER, AND MARCEL VOGEL. Luminescence of Liquids and Solids. 1943.
YARWOOD, J. High Vacuum Technique. 1943.

RAILROAD ENGINEERING.

DRANEY, JOHN. Diesel Locomotives. 1943.

SUGAR.

Sugar Reference Book and Directory. Volume 12. 1943.

WELDING.

Resistance Welder Manufacturers' Association. Resistance Welding Manual. Preface 1942.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Experimental Burns. A Summary of Work.—J. O. Ely. During the past two years a series of experimental studies has been made on burn-injured rabbits and rats. Although experimental work has been performed by others in most of these problems in relation to burns, the results have not always been in agreement. Therefore, as a basis for further work, it was considered advisable to make these studies under our own experimental conditions. A brief statement only of the work will be given here.

EXPERIMENTAL.

A. Work with Rabbits.

Male rabbits of the New Zealand White breed were fasted overnight prior to being used. The hair having been clipped closely from the body, the burns were inflicted by dipping the dehaired back into water at 94° C. for 12 seconds in most cases. The burns covered approximately 30 per cent. of the total body surface. Evipal (a 14 per cent. solution) was given intravenously to produce anaesthesia. Blood samples were obtained by heart puncture prior to inflicting the burns and at selected intervals thereafter. A summary of the results follows:

1. *Plasma calcium*. Five burned rabbits and five control rabbits were used. The control rabbits received the anesthetic and the same amounts of blood were taken from them as from the burned rabbits. In 1.5 hours after inflicting the burns there was an average decrease in the calcium content of the plasma of the burned rabbits of 10.8 per cent. and in 3 hours of 14.3 per cent. more than the decrease in the plasma of the control rabbits.

2. *Protein nitrogen and non-protein nitrogen in the serum of burned rabbits*. With four burned rabbits there was an average decrease in serum protein nitrogen of 14.4 per cent. in 1.5 hours after inflicting the burn and of 21.3 per cent. in 3 hours. In contrast to this the decrease in an unburned rabbit was 2.2 per cent. in 1.5 hours and 4.2 per cent. in 3 hours.

With these same burned rabbits there was an average increase of 18.9 per cent. in the serum non-protein nitrogen in 1.5 hours after the burn and of 47.7 per cent. in 3 hours. In contrast, the unburned animal showed a decrease of 5.8 per cent. in 1.5 hours and an increase of 13.5 per cent. in 3 hours.

3. *Chloride changes*.

a. In blood. With thirteen rabbits there was found an average decrease in blood chlorides of 7.8 per cent. in 1.5 hours after inflicting the burn, 8.2 per cent. in 3 hours and 4.2 per cent. in 5 hours.

b. In plasma. With fifteen rabbits there was found an average decrease of 3.4 per cent. in the plasma chlorides in 1.5 hours after inflicting the burn, 1.5 per cent. in 3 hours and 0.8 per cent. in 5 hours.

c. Skin chlorides. In seven burned rabbits the chloride content of the burn-injured skin was found to be 12.4 per cent. greater on the wet weight basis and 25.0 per cent. greater on the dry weight basis than unburned areas of skin of the same rabbits.

d. Muscle chlorides. In twelve burned rabbits the chloride content of the burn-injured muscle was found to be 41 per cent. greater on the wet weight basis and 39 per cent. greater on the dry weight basis than uninjured muscle of the same rabbits.

e. Subcutaneous connective tissues. In nine burned rabbits the chloride content of the subcutaneous connective tissue was found to be 10.3 per cent. less on the wet weight basis and 0.9 per cent. greater on the dry weight basis in the burn-injured areas than in uninjured areas.

The accumulation of chloride in burn-injured areas is greater than these data indicate. While analysis does not indicate an increase in the subcutaneous connective tissue on the unit weight basis, the amount of such tissue is very much greater in the burned areas (i.e. total weight including the moisture). In five rabbits the weight of a unit area of the burn-injured skin and the adherent subcutaneous connective tissue was on an average 3.5 times as great as in an uninjured area. Thus in a burn covering 30 per cent. of the body surface the accumulation of chloride containing fluid is very great.

4. *Hemoconcentration*. In thirty-three untreated burned rabbits a hemoconcentration was found with an average maximum of approximately 25 per cent. in 1.5–2 hours, dropping to about 10 per cent. in 6–7 hours after infliction of the burns.

5. *Hematocrit values*. In eight burned rabbits the hematocrit values were increased an average of 16.9 per cent. in 1.5 hours, 8.9 per cent. in 3 hours, and 4 per cent. in 5 hours.

6. *Specific gravity of the blood*. In eight burned rabbits the specific gravity of the blood was increased an average of 9.2 per cent. in 1.5 hours, 6.7 per cent. in 3 hours, and 1.7 per cent. in 5 hours after the infliction of the burns. In sixteen additional burned rabbits comparable increases were found at somewhat different intervals of time.

7. *Specific gravity of the plasma*. In eleven burned rabbits the specific gravity of the plasma was found to be decreased by 4.9 per cent. in 1.5 hours, 7.8 per cent. in 3 hours, and 7.0 per cent. in 5 hours after the infliction of the burn. In seventeen other rabbits the specific gravity of the serum was found to decrease comparable to that of plasma.

8. *Treatment for combatting the hemoconcentration of burns*. Using sixty-five rabbits divided into 4 groups, a comparison was made of the influence on the hemoconcentration of burns of a Gelatin-Glucose-Salts

solution, rabbit serum and 0.85 per cent. NaCl solution. It was found that the Gelatin-Glucose-Salts solution and rabbit serum were equally effective in combatting the hemoconcentration, whereas the 0.85 per cent. NaCl was ineffective. This work has been reported (JOURNAL OF THE FRANKLIN INSTITUTE, **235**: 197, 1943).

B. Work with Rats.

1. *Changes in the phosphorus content of muscle.* The effect of burns on the moisture content, total phosphorus, acid-soluble inorganic phosphorus, acid-soluble organic phosphorus and acid-insoluble phosphorus content of rat muscle has been reported (JOURNAL OF THE FRANKLIN INSTITUTE, **235**: 416, 1943).

2. *Changes in the chloride content of muscle.* Twenty rats were used to study the chloride content of leg muscle as influenced by burns. A burn was inflicted on the outside of one hind leg. Muscle from the opposite leg was used for comparison.

Samples of muscle taken from 1 hour to 29 hours after the burn infliction showed the chloride content of the burn-injured muscle to be increased approximately 300 per cent. over that of the uninjured leg muscle. The subcutaneous connective tissue in the burn-injured legs of four of these rats showed an increase in chloride content of approximately 500 per cent.

3. *The effect of the intravenous injection of laked blood on rats.* Blood heated to a temperature comparable to that of the tissues burned in these experiments is hemolyzed. It was considered of interest to observe the effect of intravenously injected laked erythrocytes on the rat. It was found that when a volume of approximately 2 per cent. of the blood of rats weighing about 120 g. was laked with an equal volume of distilled water and returned to the same rat (NaCl had been added to make the suspension physiological) death occurred in about 1 minute. There was an arrest of respiration, followed by convulsions. The heart continued to beat for some time after respiration ceased. Erythrocytes separated from the plasma before laking were as effective as laked whole blood.

It was decided that the size of particles, or aggregates, was responsible in some way for the deaths, the mechanism not being understood at present. That particle size was the responsible factor was determined by the fact that hemogenization of laked erythrocyte suspensions by the action of an ultrasonic oscillator yielded a uniformly fine suspension which appeared to be innocuous.

Burns may hemolyze blood or perhaps rupture the erythrocytes in the injured area. However, this does not indicate, necessarily, that such injured erythrocytes play a role in the shock of burns, because they may be fixed *in situ* by the heat.

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BOOK REVIEWS.

Meet Dr. Franklin. 234 pages, 17 × 25 cms. Philadelphia, The Franklin Institute, 1943. Price $2.50.

It is eminently fitting that The Franklin Institute should undertake to act as a center to distribute a more general knowledge of the life and achievements of Benjamin Franklin and to bring home to all Americans the value and importance of his example and teaching at the present day.

With this laudable object in view the Institute sponsored a series of addresses on various aspects of the many-sided Franklin's character and work, each of the speakers being chosen because of his special qualifications to speak on a particular aspect of the subject. These addresses were subsequently published in The Journal of The Franklin Institute, but their importance and value was so generally recognized that it was wisely and fortunately determined to give them collective publication in book form, hence the present volume. A mere list of the names of the contributors would suffice to illustrate the importance of the contents of the book, but we cannot refrain from pointing out some of the special features of the various talks.

The opening and concluding papers are by Carl Van Doren, the author of the latest and best biography of Franklin, who candidly states that he is working on a revised edition of that large work which will be half again as long as the first. Van Doren, giving a concise summary of the published works of Franklin, points out that there is no complete edition, Parton, Bigelow and Smyth's all lacking important matter either unknown to them, or, especially in Smyth's edition, deliberately omitted. Would that Van Doren would undertake the task of bringing out a complete definitive edition.

Professor Van Doren's first paper is a delightful general introduction to the "The most renowned private citizen on earth."

In "Benjamin Franklin as a Scientist," Dr. Robert A. Millikan describes in terms intelligible to the layman what Franklin achieved in the new field of electrical research. With wise candor he publishes at the conclusion of his article a letter from I. Bernard Cohen which while criticizing Dr. Millikan for devoting his paper solely to Franklin's work in electricity omits to mention his achievements in meteorology and other branches of physics, and his scientific articles published in various periodicals and pamphlets, thus filling the lacunae which Dr. Millikan had left.

Dr. Max Farrand considers Franklin's self-portraiture in the "Autobiography." Though literary critics do not class Franklin among the "great men of letters" Dr. Farrand very justly asks where one will find greater simplicity of presentation and more crystal clearness of style. The "Autobiography" remains a literary classic, its common sense, humor, the good stories which its author relates so well, will always make it popular. The Huntington Library, of which Dr. Farrand is Director, contains the original manuscript of the "Autobiography" and all lovers of Franklin, and they are very numerous, will hail the variorum edition which the Huntington Library proposes to publish, although Dr. Farrand states that the published versions made from copies of the original show few variations of importance.

"Dr. Franklin as the English saw Him," by Dr. Conyers Read, is a very valuable study of the great influence exercised on Franklin by his English inheritance and connections. Very important were his friendship and association with Priestley and Price, and with the Scotchman Lord Kames. He was more closely associated with the Unitarians and Deists than with any other religious group, although he was very intimate with the Quaker Doctor John Fothergill and with the Anglican Bishop Shipley, of St. Asaph's. Franklin was a very social being and he mingled with many persons of very different kinds during his long sojourn in London. Professor Read's study presents some new aspects of Franklin's life in London which have an important bearing on his subsequent life.

In "Franklin's Political Journalism in England," Verner W. Crane presents a number of interesting details not generally sufficiently known on a very prominent feature in Franklin's activities. Many political writings of Franklin concealed by anonymity or pseudo-anonymity have been brought to light only in comparatively recent years. It is curious that in 1779, at the height of the Revolution, Benjamin Vaughan published in London a collection of Franklin's essays which included his political as well as scientific essays, even his "Rules by which a Great Empire may be reduced to a Small One," and "An Edict by the King of Prussia." Dr. Crane shows that one reason that Franklin was able to secure quick publication in London of many of his political essays was his close friendship with Strahan and Caleb Whitefoorde, both of whom were part owners of London periodicals.

Dr. Robert E. Spiller writes of Franklin as a "Student of Life," necessarily dealing in the course of his address with Franklin's attitude towards religion, which he finds was in accord with that of the eighteenth century Deists and Unitarians. We are driven to the conclusion that Franklin would have been in accord with what Gibbon describes as the attitude of the Romans towards the religious beliefs prevailing in various parts of their great empire—they "were all considered by the people as equally true; by the philosopher as equally false; and by the magistrate as equally useful."

In his address on Franklin's part in "Molding the Constitution," George Wharton Pepper emphasizes the fact that it was Franklin's personality which accomplished so much in the Constitutional Convention, more than any other part that he played, which led the members of the Convention to adopt the Constitution, and demonstrates clearly how great a part Franklin's personality played in the successful termination of the labors of the Convention. Eye-witnesses tell us how infrequent and brief were his remarks during the Convention, yet how great was his influence in overcoming the dissensions between the representatives of the different states and even among the delegates of the states themselves. Franklin had the happy faculty of suggesting compromises which brought about united action, and finally led to the adoption of the Constitution, a service the value of which cannot be overestimated.

Bernhard Knollenberg deals with Franklin as a "Philosophical Revolutionist." He shows that Franklin did not merely accept the existing order of things, nor did he think that that order should be upset simply because it was old. He asked, "Is it right?", "Is it useful?", "Is it logical?". If not it should be changed for something better. He was temperate, cautious, shrewd, but he wished to better things whenever possible. He adhered to the English monarchy till it was clearly proven that nothing could be obtained by doing so.

"Looking Westward," by Gilbert Chinard, is one of the most interesting articles. Franklin was all for a greater America—looking westward over the mountains to the prairies. He showed that with its opportunities for expansion America would in comparatively few generations far outstrip England in population. He advocated opening up new settlements to provide room for expansion and to break French power. His vision of the new country to be settled as expressed in the "Plan" resulting from the Albany Convention in 1754 is almost lyrical in its description of the country to be settled, a country which "must undoubtedly (perhaps in less than another century) become a populous and powerful dominion." Its acquisition would prevent the junction between the French colonies of Canada and Louisiana. In the final peace treaties he insisted on freedom of navigation of the Mississippi from its source to its mouth. He would encourage immigration but warned of the hard work necessary to open up the magnificent new country—and would only welcome immigrants if of good character and willing to be Americanized.

In "The Printer at Work" Lawrence C. Wroth, after describing the low state of printing in the Colonies, old type and presses and unskilled workmen, shows how Franklin going to London in 1724 worked in the establishments successively of Palmer and Watts, and studied closely the type formation of James, all three men being active in improving the art of printing in England. Franklin was quick to adopt the beautiful new Caslon letters which were produced in 1726. Franklin upon his return knew how "to contrive a mould, make use of what letters were left as puncheons, strike matrices in lead," and thus was able to supply many deficiencies. He could also engrave on copper. Wroth draws a rather unattractive picture of

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Franklin when he was associated with Keimer and Meredith. "It would show us, I believe, the picture of a thruster, a go-getter, a superior youth unable to conceal his superiority, a calculating young tradesman very much unlike the benevolent philosopher of later years."

Franklin extended his influence greatly by aiding in the establishment and acting as silent partner in printing establishments in different places in the Colonies, Charlestown, South Carolina; Newport, Rhode Island; New York, etc.

He made printer's ink and did a large business gathering and selling rags to paper mills. He reverted to his interest in printing in his old age in France with his printing press at Passy, where he also cast types.

"Franklin's Adventures in Agriculture," by Carl R. Woodward, opens with an interesting account of the discovery that Franklin never owned and cultivated a farm near Burlington, N. J., a myth which was transmitted by Jared Sparks and John Bigelow and A. H. Smyth, all printing as a letter from Franklin to Jared Eliot, a letter really from Charles Read to Jared Eliot, now in the Sterling Library at Yale, and rightly attributed to Read, not Franklin. Franklin leased a two and one-half acre lot in the Northern Liberties—where he apparently did some cultivation, pastured a pony and possibly a cow. He also owned a farm in Chester County—probably taken in settlement of a debt, which he never occupied or cultivated. Dr. Woodward also destroys faith in the story told by Chaptal that Franklin introduced the use of lime or plaster as a manure by plastering some ground on the roadside with huge letters stating "This has been plastered." Franklin, however, was very active in interchange of plants and seeds between Europe and America and much interested in silk culture. He aided Bartram and other botanists in their work and was always actively interested in any measure to promote agriculture, but as Dr. Woodward shows he was not a practical farmer.

"Franklin, Friend of the Indians," by Julian P. Boyd, is one of the most striking contributions to the book. Franklin negotiated with the Indians on more than one occasion. We are familiar with the courage which he displayed in suppressing the outrages perpetrated upon the Indians by the so-called "Paxton Boys," and he supported the Delaware Indians in their dissensions with the proprietary government. But as Boyd points out he cannot be classed with men like Eliot or Zinzindorf as zealous for their improvement, nor did he ever acquire any influence over them such as that of Sir William Johnson, or knowledge of their history or habits such as Cadwallader Colden or Conrad Weiser, but he represented the Indians, sympathized with them, and protected them whenever in his power against the white man's aggression. Dr. Boyd presents a valuable study of a somewhat obscure facet of Franklin's activities.

We can only regret that this series of addresses could not have been extended to cover several other phases of Franklin's life; his youth, his relations with several of his intimate women correspondents, his treatment by Wedderburn and other English politicians; his military career, and his life in Paris. What is presented here is so excellent we wish for more. Of all the vast number of books written about Franklin there are few that can be read with more profit and pleasure, and none that will give greater satisfaction to the general reader.

FRANCIS R. PACKARD, M.D.

GALAXIES, by Harlow Shapley. 229 pages, photographs and illustrations, 15 × 22 cms. Philadelphia, The Blakiston Company, 1943. Price $2.50.

The "Galaxies" is a valuable contribution to the literature of astronomy. Dr. Shapley has spent most of the past twenty years establishing much of our knowledge about their nature and distribution over the face of the sky and in depth. He has been the instigator of investigations varied and multitudinous by his colleagues and students. Gradually we are beginning to see the results of the laborious tons of photographic plates made at the several Harvard observatories; the meaning of the picture is not yet evident, but at least the picture is coming to be a little less cloudy. That this book can be read by the interested layman as well as the professional with pleasure and inspiration is very important; those who are not specialists in astronomy would do better to know more about the galaxies and let intimate details go. The fresh pictures which are sprinkled so liberally through this book make it an invaluable reference work.

ROY K. MARSHALL.

LUBRICANTS AND CUTTING OILS FOR MACHINE TOOLS, by William G. Forbes. 90 pages, 14 × 22 cms., photographs and illustrations. New York, John Wiley & Sons, Inc., 1943. Price $1.50.

The title of this book suggests a work of a practical nature for all those who are associated with machine shop activities. And today such activities are widespread, making a demand for explanations of fundamental principles and practical maintenance. There are 86 pages of text in this book—a small one—but each is well focused on the subject. At the outset a description is given of standard laboratory tests carried out on new and used oils. Then the composition of greases is discussed, followed by a description of different types of machine tools and machine tool lubrication and maintenance. Following this the trend goes through the mechanics of cutting metals, the composition of cutting oils, the compounds and blends of cutting oils, practical application of cutting oils, tool design, machinability tables, and to round out the subject the last chapter is devoted to the treatment and prevention of skin diseases that result from contact with lubricants.

This book contains in brief carefully selected and abstracted parts of the more detailed book "Lubrication of Industrial and Marine Machinery" by the same author, notice of which appears in these columns.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

Statistical Adjustment of Data, by W. Edwards Deeming, Ph.D. 261 pages, illustrations, 14 × 21 cms. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1943. Price $3.50.

Second Year College Chemistry, by William H. Chapin. Fifth edition, revised by Luke E. Steiner. 575 pages, illustrations, 14 × 22 cms. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1943. Price $3.75.

Enzyme Technology, by Henry Tauber, Ph.D. 275 pages, photographs and illustration, 14 × 22 cms. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1943. Price $3.50.

Galaxies, by Harlow Shapley. 229 pages, photographs and illustrations, 15 × 22 cms. Philadelphia, The Blakiston Company, 1943. Price $2.50.

The Physical Chemistry of Electrolytic Solutions, by Herbert S. Harned and Benton B. Owen. 611 pages, tables and illustrations, 15 × 24 cms. New York, Reinhold Publishing Corporation, 1943. Price $10.00.